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THE INFLUENCE OF HORMONES ON THE DEVELOPMENT OF SILICOTIC NODULES PRODUCED BY INTRAPERITONEAL INJECTION OF QUARTZ

BY

ERICH SCHILLER

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(RECEIVED FOR PUBLICATION JULY 6, 1952)

In a previous paper (Schiller, 1951c) I put forward the view that the tissue reaction to silica was not a specific one. It is well known that cells give a common response to different types of injury (cf. Selye, 1951). It is improbable, therefore, that a particular pathogenic agent will produce an entirely new type of reaction. It is more probable that similar reactions will be produced by different agents. It is possible that the massive fibrosis found in the late stages of several types of pneumoconiosis is an example of this. By some authors (Giese, 1931 ; Wätjen, 1936 ; di Biasi, 1951) the process is believed to be due to silica, whereas, principally in South Wales, it is believed to be a modified type of tuberculosis (Husten, 1931; Gough, 1949, 1952 ; Gough, James, and Wentworth, 1949 ; Fletcher, Mann, Davies, Cochrane, Gilson, and Hugh-Jones, 1949 ; Fletcher and Gough, 1950 ; Heppleston, 1951 ; Fletcher, 1951). Both theories may well be correct.

The tissue reaction, whatever its cause, will also vary according to its immediate chemical environment, and in this paper I am dealing with the effect of certain endocrine substances on the formation of the silicotic nodule.

The inhibitory action of cortisone on proliferating connective tissue is well known. Its effect on wound healing has been studied by a great many authors (Ragan, Howes, Plotz, Meyer, and Blunt, 1949 ; Ragan, Howes, Plotz, Meyer, Blunt, and Lattes, 1950 ; Baker, 1950 ; Baker and Whitaker, 1950 ; Spain, Molomut, and Haber, 1950 ; Bangham, 1951) but their experiments only lasted a few days as did those of Taubenhaus and Amromin (1949, 1950). The most important finding seems to be that of Castor and Baker (1950), who maintained complete inhibition of hair growth in rats treated locally with a hog adrenal extract for about 160 days. After this hair began to grow again in spite of continued treatment. Microscopic examination of the skin showed that recovery had been almost complete. Magarey and Gough (1952) reported an inhibitory effect on intraperitoneal silicosis in the mouse, a depressant effect in the rat, and no effect in the guinea-pig. They gave a somewhat different dose of cortisone in relation to body weight, e.g. 125 mg./kg. in the mouse, 28·5 mg./kg. in the rat, and only 16·5 mg./kg. in the guinea-pig. But in rabbits given only 8 mg. cortisone/kg. Magarey and Gough (1952) found a delay in the appearance of fibrosis. In using high doses of cortisone there is a risk of producing that atrophy of the adrenal cortex mentioned by Curran (1952) in his mice treated with 0·4 mg. cortisone daily.

For these reasons I decided to stimulate the adrenal cortex to produce cortisone itself, using oestrogens, insulin, and thyroxine.

The mode of action of oestrogens is rather doubtful. Selye (1940) reported an enlargement of the adrenal cortex of male rats given 300 μg. oestradiol daily for three weeks. Brand (1949) produced a doubling of the adrenal weight by 0·5 mg. stilboestrol in 10 days. Baker (1949) and Baker and Whitaker (1949) found that the impairment of hair growth by oestrogen was abolished after adrenalectomy. Ingle and Baker (1951), however, assume that the hormones of the adrenal cortex only play a supporting role. The hypoglycaemic reaction produced by high doses of oestrogen (Larizza and Ventura, 1951) must also be considered.

Insulin hypoglycaemia raises the A.C.T.H. level of human blood (Bartelheimer and Cabeza, 1942), the extract of which induces an adrenal enlargement in mice. Cuatrecasas (1949), Godlowski (1949), Kersley, Mandel, Jeffrey, Desmarais, and Bene (1950), and Kresbach and Stepantschitz (1951) tried

insulin in rheumatoid arthritis with encouraging success. Henderson, Gray, Weinberg, Merrick, and Seneca (1950), who gave insulin together with cortisone, had less convincing results. Vogt (1950) attempted to explain this discrepancy by arguing that injected cortical hormones inhibit the pituitary response to stress :

" By giving the insulin along with the cortisone the physician defeats his own ends, because he prevents the very release of A.C.T.H. which presumably constitutes the beneficial action of insulin in rheumatoid arthritis."

Thyroxine induces a hypertrophy of the adrenal cortex (Durey, 1949 ; Tuchmann-Duplessis, 1951). Its distinct corticotrophic action is also mentioned by Selye and Stone (1950).

While high concentrations of desoxycorticosterone inhibit fibroblastic proliferation in tissue cultures (von Möllendorff, 1943 ; Meier, Gross, Desaulles, and Schär, 1952), low concentrations do not produce any effect (Meier and others, 1952) or accelerate the course of individual mitosis (von Möllendorff, 1942). *In vivo* Taubenhaus and Amromin (1949, 1950) found an increased activity of fibroblasts.

Testosterone may restrict connective tissue formation by inhibition of anterior pituitary growth hormone (Taubenhaus and Amromin, 1950) as the simultaneous application of testosterone plus somatotrophin does not show this effect.

General Methods

Owing to the length of time required to obtain a reaction to silica by inhalation, the intraperitoneal technique was used. Albino mice, varying in weight from 18 to 24 g., were injected intraperitoneally with a single dose of 10 mg. quartz suspended in 0·1 ml. saline solution. Quartz, 1 g., was sterilized by hot air and suspended in 10 ml. saline solution by an ultrasonic technique. Of the particles, 79·55% were below 2 μ measured by the Leitz phase-contrast equipment. The size and shape of the particles under the electron microscope are shown in Figs. 1 and 2.

The mice were divided into seven groups.

The mice in group I (152 male amd two female animals) remained untreated and served as controls.

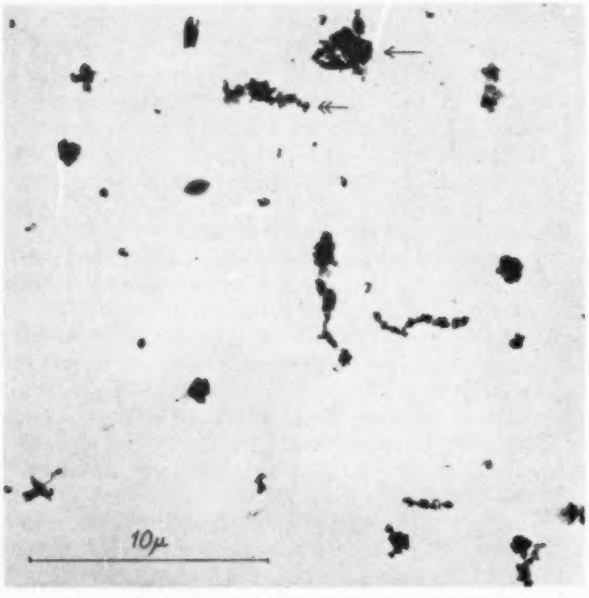


FIG. 1.—The quartz dust used in these experiments under the electron microscope (by courtesy of Dr. Walkenhorst, of Bochum).

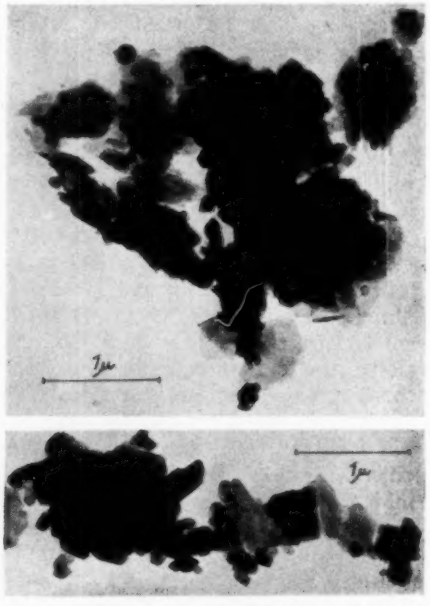


FIG. 2.—Details of the aggregates of particles indicated by arrows in Fig. 1.

Of the particles, 79·55% were below 2 μ measured by the Leitz phase-contrast equipment. The size and shape of the particles under the electron microscope are shown in Figs. 1 and 2.

> 20 μ	0·33%
10—20 μ	0·99%
4—10 μ	3·63%
2— 4 μ	15·50%
< 2 μ	79·55%
	100·00%

TABLE

SUMMARY OF RESULTS AND DOSES GIVEN

Group	Hormone	Period of Application (Days after Quartz Injection)	Single Dose (μg.)	Total Dose	Number of Animals	
					Injected	Surviving*
I	—	—	—	—	152 males } 2 females }	100 males } 1 female }
II	Cortisone	1st–7th 8th–death	200 μg 100 μg	(3·6 mg)	7 males	0
		21st–29th	20 μg	180 μg	10 males	8
III	Cyren B	1st–39th	0·25 μg	9·75 μg	20 males	7
IV	Insulin	1st–29th	0·004 i.u.	0·116 i.u.	10 males	5
		1st–59th	0·004 i.u.	0·236 i.u.	10 males	3
V	Thyroxine	1st–29th	0·25 μg	7·25 μg	10 males	9
VI	D.O.C.A.	1st–29th	125 μg	3,625 μg	7 males	4
VII	Testoviron	1st–29th	50 μg	1,450 μg	7 males	3

* All showed in varying degree the changes described.

The mice in group II (seven male animals) were injected subcutaneously with one daily dose of 200 μg. cortisone " ciba ", beginning on the second day of the experiment. After seven days of such injections the dose was reduced to 100 μg. daily. As all these mice died within 18 days (cf. Magarey and Gough, 1952) and could give no reliable results, this experiment was repeated (10 male animals) with a dose of 20 μg. cortisone daily, the injections beginning on the twenty-first day after the intraperitoneal injection of silica. Two animals died on the twenty-fifth day after the beginning of the experiment and the surviving eight were killed on the thirtieth day.

The mice in group III (20 male animals) were injected subcutaneously with one daily dose of 0·25 μg. diethylstilboestrol-dipropionate (Cyren B Bayer), beginning on the second day of the experiment. The surviving seven were killed on the fortieth day after the beginning of the experiment.

The mice in group IV (20 male animals) were injected subcutaneously with one daily dose of 0·004 I.U. of " depot insulin Hoechst ", beginning on the second day of the experiment. Five animals were killed on the thirtieth day after the beginning of the experiment, and three on the sixtieth day.

The mice in group V (10 male animals) were injected subcutaneously with one daily dose of 0·25 μg. thyroxine (" roche ") beginning on the second day of the experiment. One animal died on the seventh day after the beginning of the experiment and the surviving nine were killed on the thirtieth day.

The mice in group VI (seven male animals) were injected subcutaneously with one daily dose of 125 μg. Doca (" cortiron schering "), beginning on the second day of the experiment. Three animals died on the seventh, fourteenth, and thirtieth day after the beginning of the experiment respectively, and the surviving four were killed on the thirtieth day.

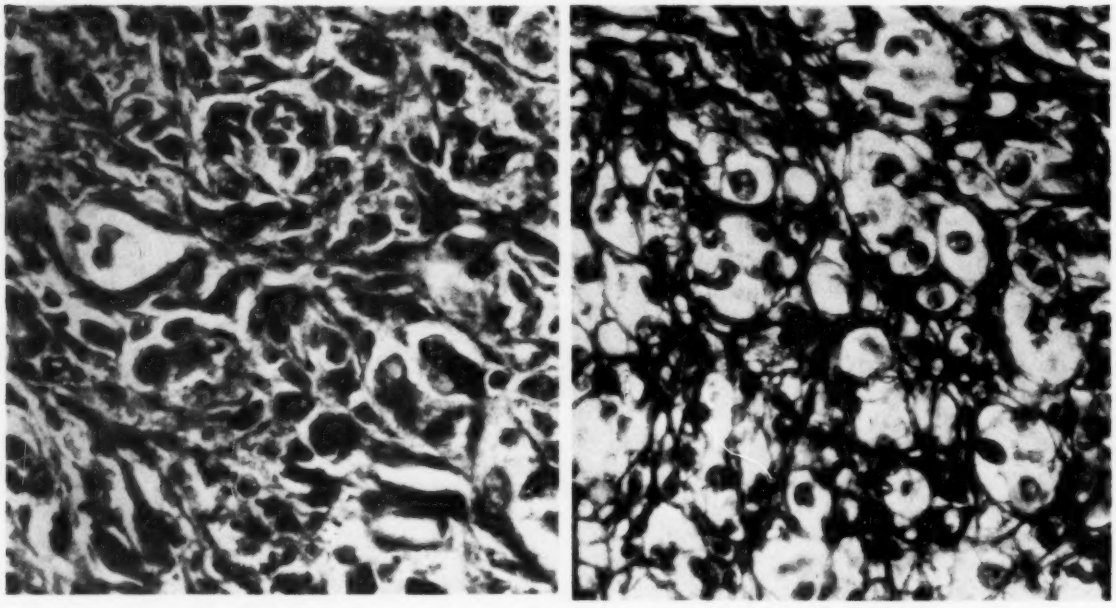
The mice in group VII (seven male animals) were injected subcutaneously with one daily dose of 50 μg. testosterone propionate (" testoviron schering "), beginning on the second day of the experiment. Four animals died and the surviving three were killed on the thirtieth day after the beginning of the experiment.

Specimens of silicotic nodules, liver, spleen, kidneys, adrenals, hypophysis, gonads, thyroid, and lymph nodes were fixed in formaline or Carnoy's fluid, embedded in paraffin and sectioned at 6 μ. The slides were stained with haematoxyline-chromotrop 2 R, Azan, using Heidenhain's technique, and for reticulin Gömöri's technique. Frozen sections were stained for fat with Sudan III.

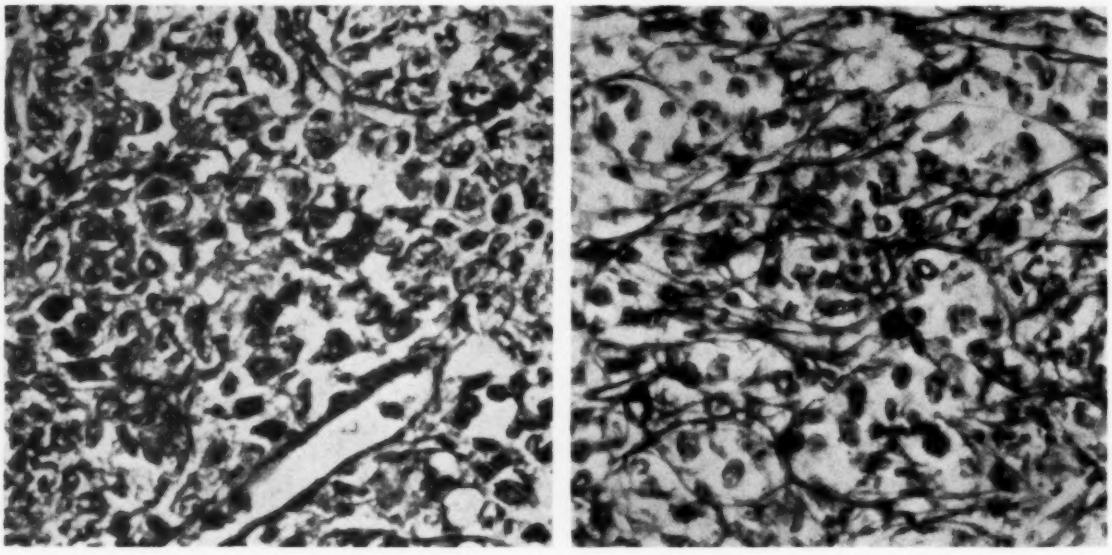
Results

Group I.—Well defined nodules became evident within one month. Their histological appearance varied according to their size and position. The largest granulomas had a necrotic centre surrounded by a zone of fibroblasts, histiocytes, lymphocytes, and leucocytes (Fig. 3). Both reticulin and collagenous fibres were present (Fig. 4). Some small nodules were hyalinized.

Group II.—Cortisone, though given only from the twenty-first day of the experiment, caused the lymphocytes to disintegrate. The resulting debris was found on the thirtieth day (Fig. 5). Only a fine reticulum was present (Fig. 6), but other organs, rich in hyaluronic acid, appeared swollen. No silica was found in the liver whereas Policard and Tuchmann-Duplessis (1951) found some in rats treated with A.C.T.H. All the silica had become adherent to the omentum, parietal peritoneum, and mesentery before the beginning of the cortisone treatment.



FIGS. 3 and 4.—From group I (peritoneum parietale of animal No. 75/51 killed on the thirtieth day after the intraperitoneal injection of quartz).

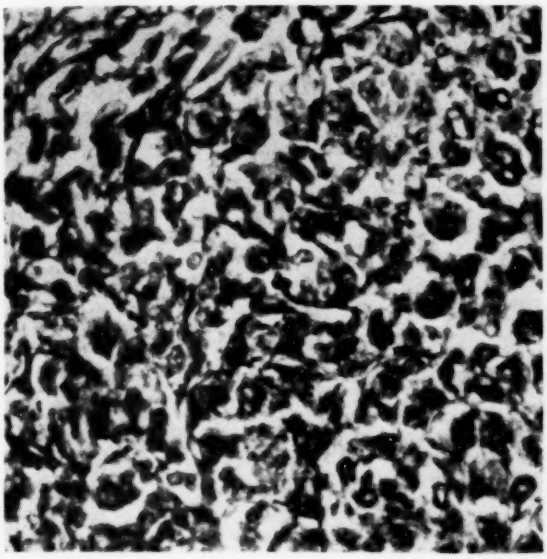


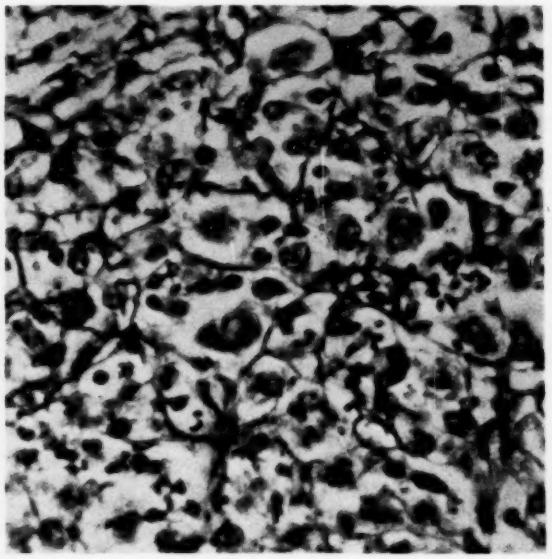
FIGS. 5 and 6.—From group II (omentum of animal No. 65/51 killed on the thirtieth day).

FIGS. 3 to 16.—Photomicrographs of tissue sections from quartz nodules of male animals from the different groups.

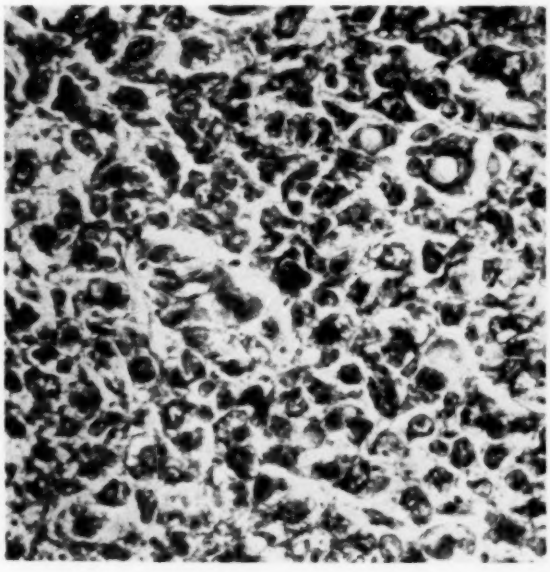
All specimens are fixed in Carnoy's fluid. The left series is stained for cells with haematoxylin-chromotrop 2 R (Figs. 3, 5, 11, 13, and 15) or azan (Figs. 7 and 9). All sections of the right series are stained for reticulin after Gömöri.

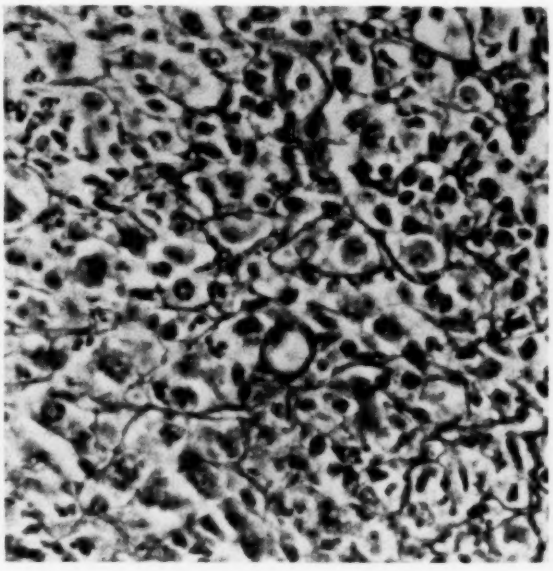
Photomicrographs are taken by the Leitz phase-contrast equipment showing phase contrast after Zernike.





FIGS. 7 and 8.—From group III (omentum of animal No. 106/51 and peritoneum near the ductus deferens of animal No. 107/51 respectively, both killed on the fortieth day).

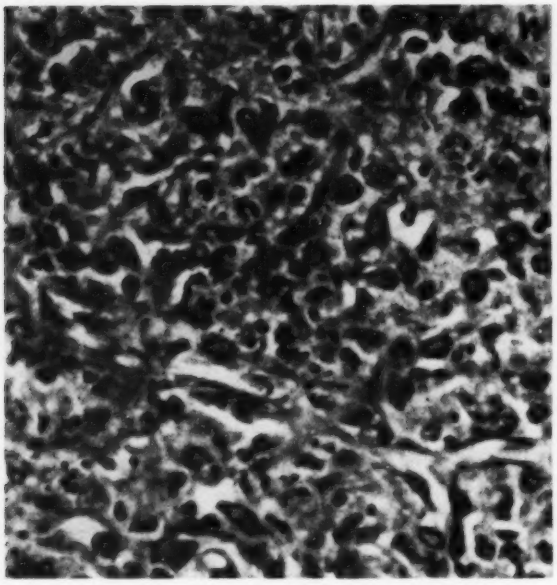


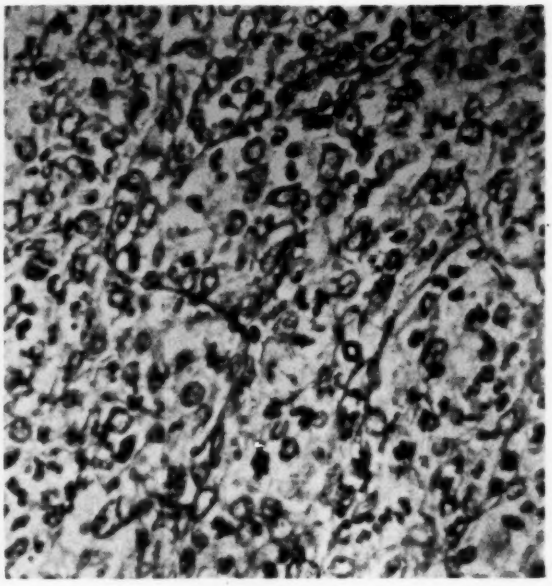


FIGS. 9 and 10.—From group IV (peritoneum parietale of animal No. 150/51 killed on the sixtieth day).

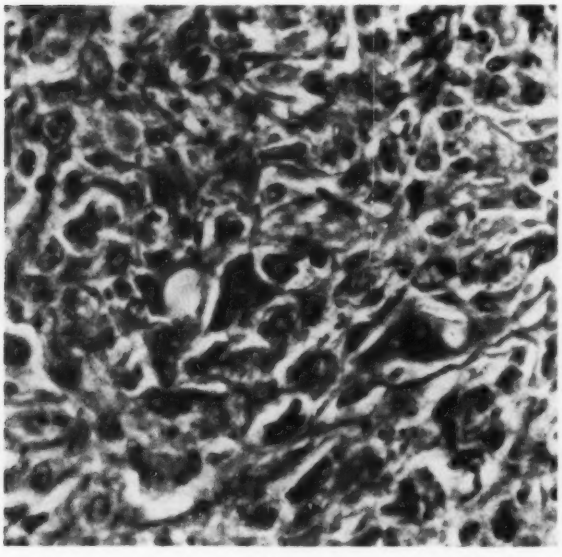
Group III.—The mice treated with "cyren B" (Figs. 7 and 8) showed an effect similar to those in group II. The injection of hormone was started on the second day of the experiment in these mice, and some quartz was found in the lymph nodes and livers forming quartz nodules with a fine reticulum there.

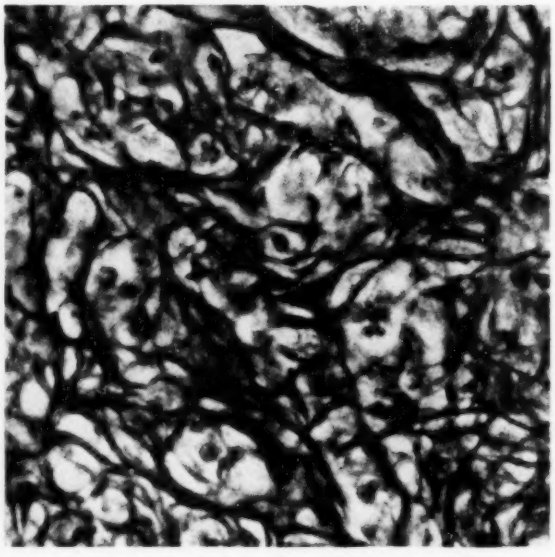
Group IV.—Insulin retarded the formation of connective tissue so much that there was only a very fine network of reticulin on the sixtieth day (Figs. 9 and 10). As in the previous group some quartz nodules with a fine reticulum were found in the lymph nodes and livers.





FIGS. 11 and 12.—from group V (animal No. 15/52 killed on the thirtieth day). Fig. 11 is taken from the peritoneum near the epididymis.

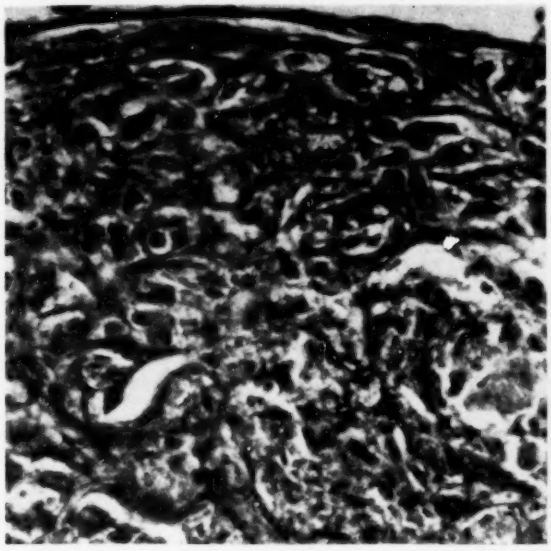


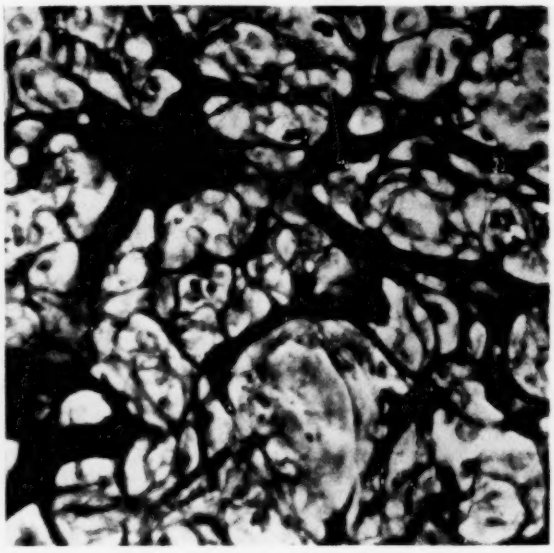


FIGS. 13 and 14.—From group VI (omentum of animals No. 30/51 and 29/51 respectively, both killed on the thirtieth day).

Group V.—Thyroxine inhibited fibrosis (Figs. 11 and 12) in the same way as cortisone. Small quartz nodules were found in the lymph nodes of these mice.

Group VI.—Desoxycorticosterone acetate increased the fibroblastic proliferation (numerous mitoses) and the formation of collagen fibres (Figs. 13 and 14) and produced widespread infiltrations of lymphocytes, especially in the liver. Multinucleated giant cells appeared both in the silicotic nodules and in the liver.





FIGS. 15 and 16.—From group VII (surface of the adrenal of animal No. 35/51 and surface of the liver of animal No. 38/51 respectively, both killed on the thirtieth day).

Group VII.—Testoviron also increased the formation of connective tissue. In particular, the ground substance and the collagenous fibres were prominent (Fig. 16), while the fibroblasts appeared as small, spindle-shaped and pyknotic cells (Fig. 15).

The above results with the doses given are summarized in the table on page 3. All surviving animals showed the reactions described but the degree of reaction will be reported in another paper.

Discussion

Cortisone, insulin, and thyroxine retarded the development of fibrosis in just the same way, affecting both the cellular constituents of the nodules and the ground substance with its derivatives. The essential constituent of the ground substance is hyaluronic acid, a muco-polysaccharide, the state of which may be controlled by enzymes secreted from the fibroblasts (Gersh and Catchpole, 1949). Thus the behaviour of this type of cells seems to be of special interest in the different groups of animals. The silicotic nodule conforms with other proliferating tissues in the scarcity of fibroblasts and ground substance after cortisone treatment, as described in wound healing by Ragan and others (1950).

The stress caused by silica may be mechanical or chemical. But Kettle's (1932) experiments, in which he coated the surface of the quartz with iron oxide, are generally accepted as ruling out the possibility of a simple mechanical action. An extremely fine amorphous silica (20 angstrom silica) has a high solubility, and is rapidly fatal to animals when injected in large amounts, while in smaller amounts its introduction in the lungs does not produce any fibrosis (King, 1947). This high fatality may be depressed by giving cortisone (Schiller, 1952). The microscopic examination of mice that died within 24 hours after the intraperitoneal injection of 10 mg. of such a fine silica, revealed the signs of severe stress, e.g. disintegration of thymus lymphocytes. A mixture of 9 mg. of the dust used in this paper plus 1 mg. of a 200 angstrom silica produced an effect on silicosis in the peritoneal cavity similar to that caused by the injection of cortisone (Schiller, 1952). These experiments suggest the possibility that pneumoconiosis may be a disease of adaptation. If this is so, we cannot expect cortisone, A.C.T.H., or any of the other beneficial hormones studied here to have a lasting effect in its treatment. It is, however, suggested that it might be of interest to investigate the hormonal constitution of miners.

Summary

The formation of silicotic granulomas after intraperitoneal injection of finely powdered quartz can be influenced by the regular injections of hormones. Cortisone, oestrogens, insulin, and thyroxine showed an inhibitory effect, while desoxycorticosterone

acetate and testosterone propionate increased the formation of connective tissue.

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THE ACTION OF DIFFERENT FORMS OF PURE SILICA ON THE LUNGS OF RATS

BY

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Pure silica (SiO_2) exists at room temperature in the four different modifications: quartz, tridymite, cristobalite, and fused silica. The first three are crystalline, but fused silica is a non-crystalline solid, a glass. Tridymite, cristobalite, and fused silica are metastable, but at room temperature they do not invert within measurable time to the only thermodynamically stable modification, quartz.

It can be regarded as proven that quartz can produce tissue changes in the lungs of animals similar to those found in human silicosis. It was also thought up to quite recently that silica was unique in producing such changes. Experiments with *r*- and *l*- quartz (King, Rogers, Gilchrist, and Nagelschmidt, 1945) had shown that there was no difference in the action of either of the optically active forms from the effect of the racemic type.

It was thought desirable next to test the effect of the four different modifications of silica under comparable conditions. The only previous information in this field came from Gardner (1938) who had injected rabbits by the ear vein with 1 g. lots and had found progressive nodular fibrosis of the liver with quartz and fused silica, but a more severe diffuse fibrosis with cristobalite and a still more rapid reaction with tridymite which resulted in the death of all his animals within three months or less. Gardner stated that his samples were analysed and were all below 3 micron diameter, but he did not give any results of analyses or counts.

We decided to make comparable sized fractions of the four silica modifications and to use them for intratracheal injection into rats in order to study the effect of the crystal structure on the type and amount of tissue reaction.

Description of Samples

Quartz.—This was prepared from a Belgian glass sand of high purity.

Cristobalite.* —Cristobalite was prepared by heating Loch Aline sand for one hour at 1620° C. without using any flux.

Tridymite.*—Tridymite was prepared by dissolving the glassy impurities from a silica cement, which had had long service at approximately 1380° C. in a gas retort house.

Fused Silica.—Fused silica was obtained from the Thermal Syndicate. It had been made from pure quartz crystals from Madagascar.

The Belgian glass sand contained 99·2% silica and the other materials 99·5% or more by chemical analysis.

Fractions below 2 microns were prepared from the four samples by repeated sedimentation in water. Before this was done the cristobalite, tridymite, and the fused silica were ground in a mechanically driven agate mortar.

Chemical analyses, solubilities, and size distributions of the samples are given in Table 1. Fig. 1A shows *x*-ray diffraction diagrams and B, C, D, and E show electron micrographs of the samples. The diffraction diagrams agree with those given in the literature, and there is no indication of contamination by other silica modifications, except for the tridymite, which shows the strongest quartz line at 3·34° A as a very faint line, indicating 0·5 to 3% of quartz.

Preparation of Dust Suspensions

Amounts of 2 g. of the individual dusts (fused silica, quartz, cristobalite, and tridymite) were weighed into 100 ml. conical flasks, and were mixed well with 60 ml. of sterile physiological saline. The final concentrations were thus 50 mg. of the individual dust in 1·5 ml. of suspension. These flasks were covered with rubber caps, and were sterilized by heating in a boiling water bath for 10 minutes on the day of the injections.

*The cristobalite and tridymite were kindly supplied in 1946 by Mr. E. H. M. Badger of the Gas, Light and Coke Co., now the Fulham Laboratory of the North Thames Gas Board, and the fused silica by Dr. A. E. F. Vickers of the Thermal Syndicate.

TABLE 1
ANALYSIS AND PARTICLE SIZE DISTRIBUTION OF SAMPLES OF FREE SILICA

Size (μ)	Fused Silica		Quartz		Cristobalite		Tridymite	
	% by No.	% by Mass	% by No.	% by Mass	% by No.	% by Mass	% by No.	% by Mass
0·45	37	1·9	26	0·8	32	2·4	15	0·4
0·45–0·64	19	2·7	16	1·6	25	5·2	13	1·1
0·64–0·90	17	7·2	18	4·8	23	12·1	18	4·1
0·90–1·30	14	16·0	18	13·5	15·5	26·3	27	17·3
1·30–1·80	8	27·0	14	29·8	5·7	26·1	17	31·1
1·80–2·60	4·8	44·5	7·8	46·4	1·65	27·6	9	45·3
2·60–3·60	0·2	0·2	0·2	3·4	0·15	0·3	1	0·7
3·60–5·10								
Particles counted	689		388		457		402	
Surface area (m^2/g.) ..	2		1·9		2·6		1·8	
Silica solubility (mg.SiO_2/100 ml.)	14·4		13·7		13·4		13·1	
Analysis : SiO_2	99·4		98·2		99·3		99·2	
Ignition loss (%)	0·16		1·0		0·6		0·4	

Animals

Thirty male rats were used for each of the dusts. They were from Worcester white strain, and their average weight was 250 g.

Experimental Procedure

The dust suspension was injected into the lungs of the animals intratracheally following the technique of Kettle and Hilton (1932), modified by Belt and King (1945), King, Gilchrist, and Rae (1947) and King, Harrison, and Ray (1949). The rats were anaesthetized lightly with ether and the trachea was exposed by blunt dissection. The flask containing the dust suspension was well shaken, and 1·6 ml. (0·1 ml. allowed to be retained in the syringe) was withdrawn into a 5 ml. syringe to which a short sharp needle (1 in. × 28 gauge) was fitted. The syringe was then kept agitated until the time of injection to prevent sedimentation within it. To obtain a good dispersion of the dust into the lung alveoli the injections were made quickly and with a certain amount of force. The wound was closed by a single suture. There were no anaesthetic or post-operative deaths.

Mortality of Animals

During the course of the experiment 11 of the fused silica group animals died, 18 of the quartz, 19 of the cristobalite, and 20 of the tridymite.

One rat from each of the fused silica, quartz, and tridymite group and two from cristobalite were lost by cannibalism. There was a large number of deaths early in the experiments, especially in the quartz, cristobalite, and tridymite groups (10, 17, and 18 deaths respectively within the first 120 days), so it was not possible to obtain exactly equal days of survival in all the experiments. However, sufficient intervals were maintained between the killings to extend all the experiments up to a year. At this time six rats remained alive in the fused silica group, and they were killed at intervals, extending the experimental period up to 450 days.

Histological Technique

Routine necropsies were carried out on both the dead and killed rats. In the case of the former the lungs were distended with the fixative (about 10 ml. of 10% formol saline) after their removal from the thoracic cavity, since satisfactory replacement could not be obtained otherwise, and in order to study the naked eye appearances of the lungs and pleura *in situ*. In the case of the killed rats, the fixative was injected intratracheally after expressing the air out of the lungs without opening the thoracic cage.

After preliminary fixation blocks were selected along the long axes of both the lungs at the level of the hilum to include the hilar lymph nodes and to take maximum representative areas for histology. The fixation was completed in fresh fixative, and blocks embedded in paraffin wax and sectioned at 5μ. Four serial sections were mounted from each block. The first was stained with Gordon and Sweet's silver impregnation, the second with haematoxylin and eosin, the third was micro-incinerated, and the fourth was kept as spare, e.g. for Gram's stain to exclude infection in some cases.

Gross Appearance of the Lungs

Macroscopically the lungs of the animals that were killed at intervals in both series of experiments did not vary much, except in the tridymite group. The subpleural collections of the dust, although scattered, were more marked in the posterior aspects of both the lungs. These areas were greyish-white, and varied in size from about 1 to 5 mm. In the case of fused silica they remained almost discrete throughout the experimental period. They appeared to be confluent by the second month in the tridymite group, while in all the other groups confluence of the lesions was noted only in the last three or four months of the experiment. The cut surface of the lungs showed a large number of

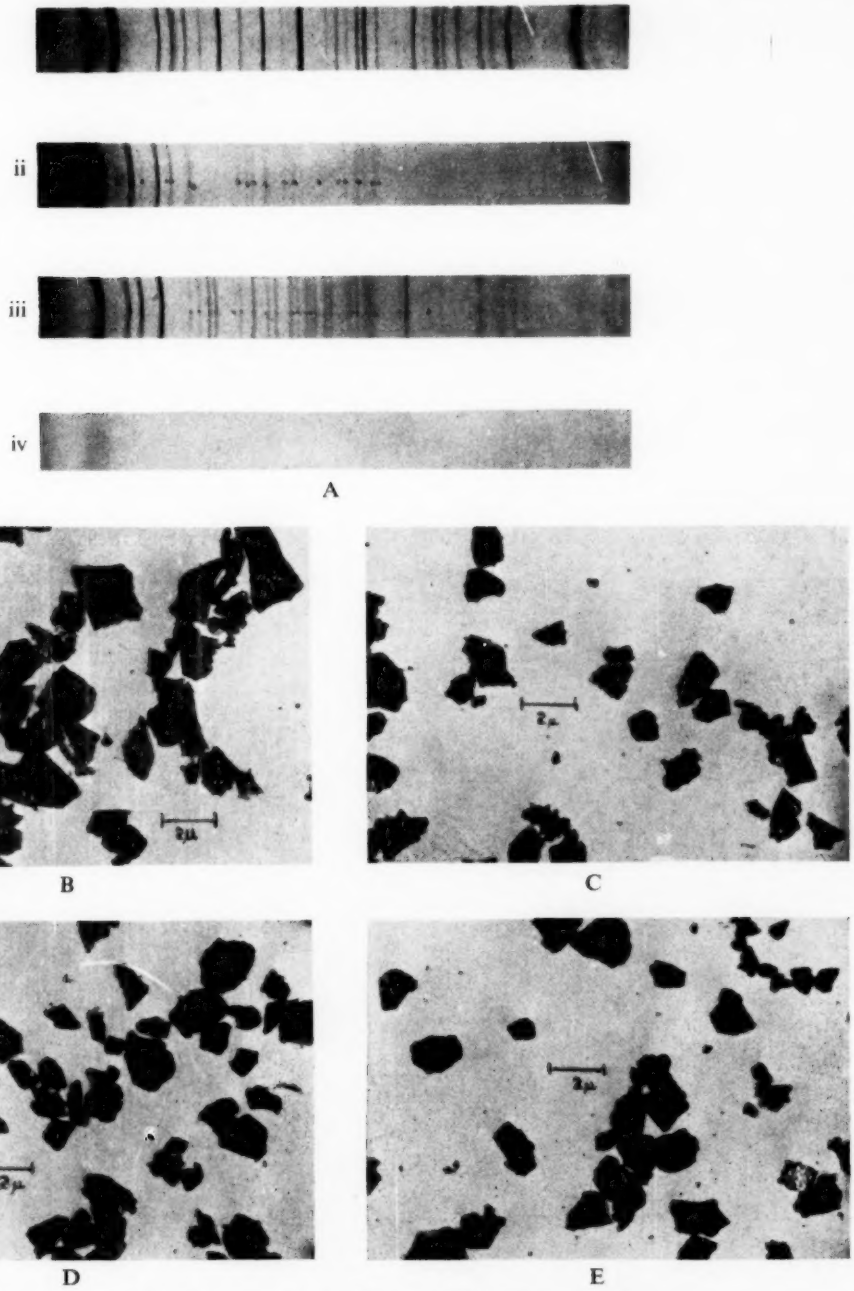

FIG. 1.—(A) *X*-ray diffraction pattern of dusts : (i) quartz, (ii) tridymite, (iii) cristobalite, (iv) fused silica.
(B) Electron micrograph of the fused silica dust : (C) of quartz ; (D) of tridymite ; (E) of cristobalite. (× 8,000.)

greyish, firm, nodular areas. The lungs of the animals that died were dark and haemorrhagic, and the dust lesions were less prominent. Some of these animals had lung abscesses. (In a few cases the abscesses almost completely replaced the lung parenchyma and these animals were discarded

from the series.) The tracheo-bronchial lymph nodes were enlarged to several times their normal size, and were firm and gritty.

Microscopic Appearance of the Lungs

Sections from the lungs of the rats were examined, and the pulmonary fibrosis seen in the most advanced lesions in each animal was graded according to Belt and King (1945). The pathological gradings so obtained, with the survival days of the killed animals, have been summarized in Table 2.

The four different forms of free silica used in these experiments produced appreciably different reactions, both in rate and severity, in the lungs of the animals. The amorphous silica (fused silica) caused a moderate degree of pulmonary fibrosis (grade 3 maximal), which was less than that caused by the crystalline silica. Of the three different forms of crystalline silica, natural quartz produced the usual classical lung pathology. It showed a remarkably steady progression of the fibrosis as the experiment proceeded, and the maximum degree was attained by the ninth month. The two other conversion forms of quartz, cristobalite and tridymite, produced more severe and rapid fibrosis of the lungs. The tridymite was outstanding. It proved to be extremely pathogenic within a very short period, and the reaction produced was different. The fibrosis was more diffuse in character than nodular, probably because of the speed of its production, and the maximum degree (grade 5) was reached by the sixtieth day. The cristobalite was less toxic but caused a more rapid reaction than the quartz, the degree of fibrosis remaining always about one month in advance of that obtained with quartz (grade 5 in eight months).

TABLE 2

SUMMARY OF PATHOLOGICAL CHANGES IN THE LUNGS OF RATS PRODUCED BY DIFFERENT FORMS OF FREE SILICA

Days of Survival	Fused Silica		Quartz		Cristobalite		Tridymite	
	Mode of Death	Grade of Fibrosis*	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis	Mode of Death	Grade of Fibrosis
1–30	D(4) K(1)+	1 min.	K(1)+	1	D(1) K(1)+	2 min.	D(2) K(1)+	1 1
31–60	K(1)	2	K(1)	2	D(2) K(1)	3 min.	D(9) K(1)+	5 min.
61–90	K(1)	2	K(1)	2	D(13) K(1)	1 3	D(3) K(1)	5 min.
91–120	K(1)	2 max.	D(10) K(1)	3	D(2) K(1)	1 3	D(3) K(1)	5
121–150	D(1) K(1)+	2 max.	D(3) K(1)+	1 3	D(1) K(1)+	3	D(1) K(1)	4 max.
151–180	D(2) K(1)	2	D(1) K(1)	2 max.	K(1)	3	D(2) K(1)	5
181–210	D(1) K(1)	3	D(2) K(1)	3	K(1)	3	K(1)	5
211–240	K(1)	1	D(1) K(1)	4	K(1)	5		
241–270	K(1)	3	D(1) K(1)	5				
271–300	K(1)	3	K(1)	5	K(1)	4	K(1)	5
301–330	D(1) K(2)+	3	K(1)+	5	K(1)+	5	K(1)+	5
331–365	D(1) K(2)	3 max.	K(1)	5	K(1)	2	K(1)	5
366–390	D(1) K(2)	3						
391–420	K(2)	3						
421–450	K(1)	3						

+ Sections from these animals are reproduced in figures.
K = killed ; D = died ; the figure within brackets indicate number of deaths or killings during stated period.
Max. = maximal ; min. = minimal within the indicated group of fibrosis.
*Grade of maturity of fibrosis : 1, loose reticulin fibrils with no collagen ; 2, compact reticulin with or without a little collagen ; 3, somewhat cellular but made up mostly of collagen ; 4, wholly composed of collagen fibres and completely acellular ; 5, acellular, collagenous, and confluent.

In all cases there was subpleural drift of the dust, and pleural involvement, patchy over the underlying lesions, was seen in the form of sessile adhesions. Dust cells, singly or in small groups, were present in some alveoli ; pulmonary emphysema of mild degree was seen.

Detailed Histological Findings

Fused Silica.—This dust produced only a moderate degree of pulmonary fibrosis even though the experiment was extended beyond one year (see Table 2). The first animal that was killed, at the thirtieth day, showed a good dust cell reaction in the lungs ; the dust-laden cells were diffusely scattered throughout the lung fields, and some were collected into small aggregations in certain perivascular and peribronchial regions. Occasionally, a slight increase of fine reticulin fibrils was seen within such nodular collections (grade 1 fibrosis minimal, Fig. 2). By the sixtieth day the nodules were well defined and composed mainly of fibroblasts. The reticulin fibres were thicker and more closely packed, with slight collagen formation in some nodules (grade 2 fibrosis). The animals, killed between this period and the 180th day, did not show any further advancement of the fibrosis than grade 2. At the 150th day the lesions appeared to be maximum within the limits of grade 2 fibrosis (Fig. 6). By the 210th day further progress of fibrosis was seen. The nodules were larger and irregular, some partly acellular, while a few others were only slightly cellular. The coarse reticulin fibres were tightly packed and arranged in the typical whorled pattern. The acellular areas were fully collagenous (grade 3 fibrosis). All the animals killed after this period up to the end of one year (except one at the 240th day which showed grade 1 fibrosis only) had similar lung lesions ; the fibrosis never exceeded grade 3 (Fig. 10). In the last one the lesions were a little advanced for grade 3, but owing to their not being completely acellular they were assessed as grade 3 maximal. Free dust cells either singly or in small groups were seen in the lung fields of the majority of the animals. Some showed a good dust cell reaction within the hilar lymph

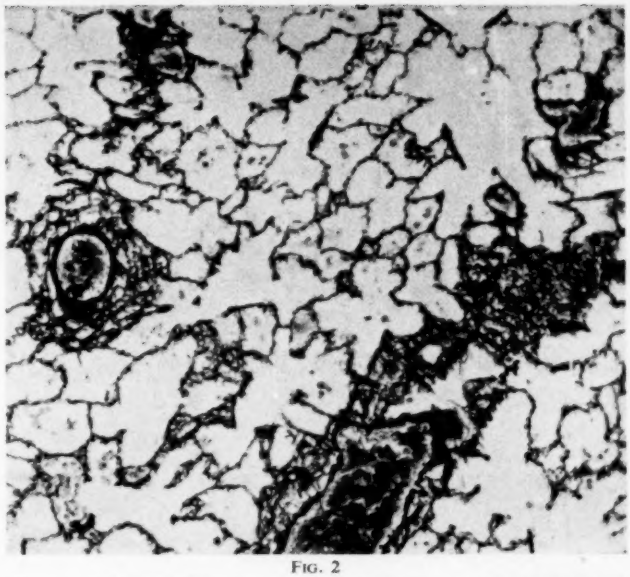

FIG. 2

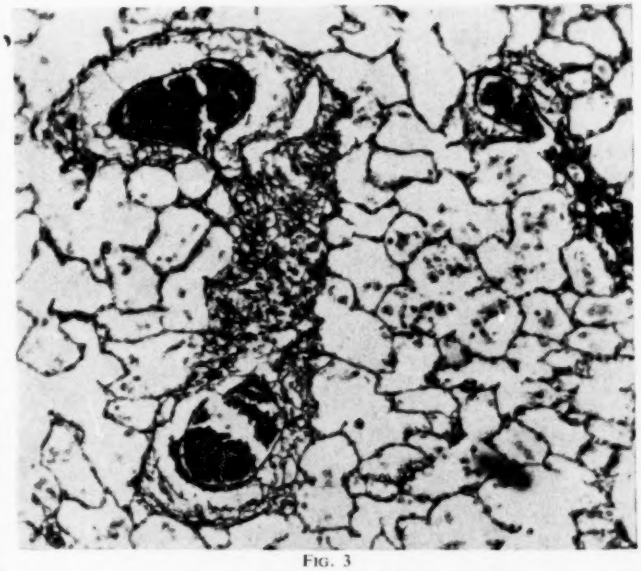

FIG. 3

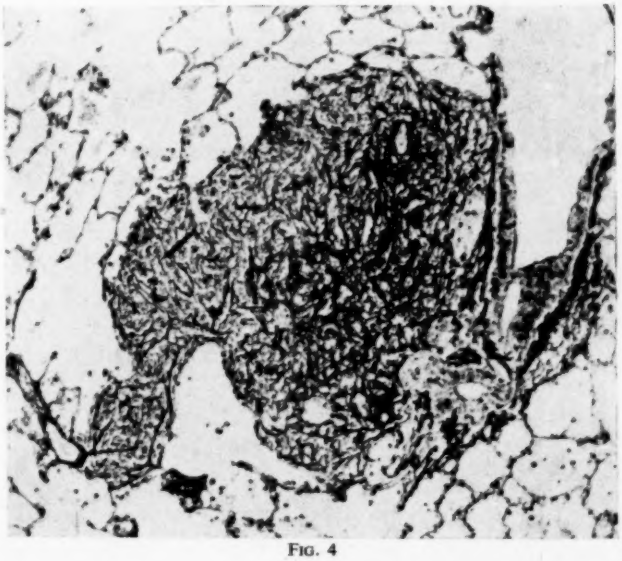

FIG. 4

FIG. 2.—Rat lung 30 days after 50 mg. of amorphous silica (fused silica) dust. Nodules with very fine and loose network of reticulin fibres (grade 1 fibrosis, minimal). (Silver impregnation, ×100.)

FIG. 3.—Rat lung 30 days after 50 mg. of quartz dust showing a nodule with fine and loose reticulin fibres within (grade 1 fibrosis). (Silver impregnation, ×100.)

FIG. 4.—Rat lung 30 days after 50 mg. of cristobalite dust showing one large nodule near a bronchiole, with coarse and compact reticulin in the centre, but fine and loose at the periphery (grade 2 fibrosis, early). (Silver impregnation, ×100.)

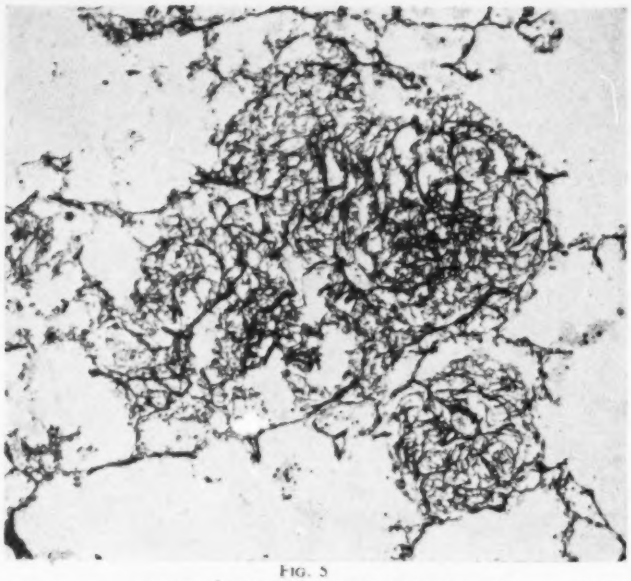

FIG. 5

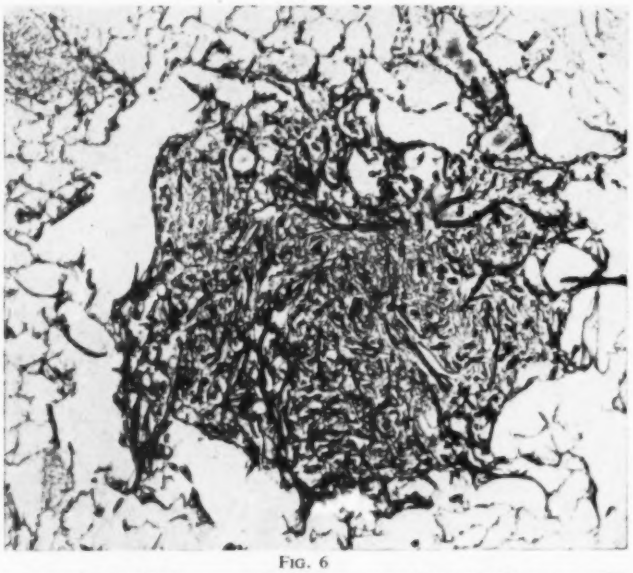

FIG. 6

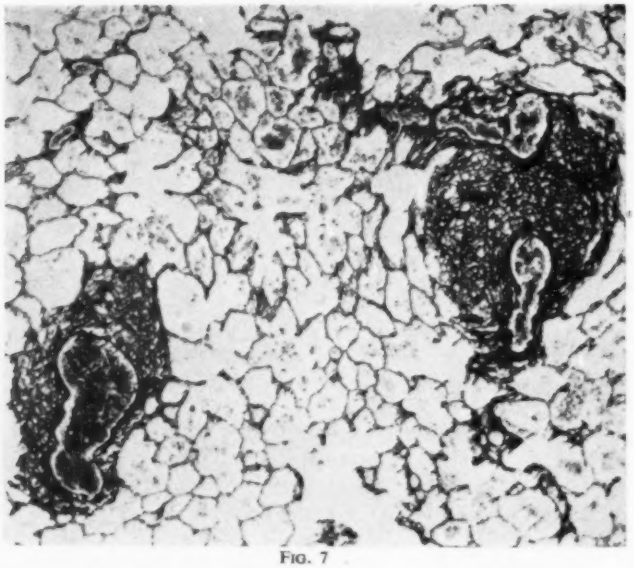

FIG. 7

nodes. Six animals remained at the end of a year and these were killed at intervals extending the experiment up to 450 days. None of them showed any further advance of fibrosis.

Quartz.—The quartz produced classical silicotic lesions in the lungs of the animals, with a steady progress in the degree of pulmonary fibrosis (summarized in Table 2). At the thirtieth day the lungs showed evenly distributed small, rounded collections of dust cells, mainly in relation to the smaller vessels and bronchioles, some intra-alveolar. The rest of the lung fields was clear, and no exudation was present. Reticulin fibres within these nodules were thick, but were tangled in a loose meshwork (grade 1 fibrosis, Fig. 3). In the lungs of the animal, killed at the sixtieth day, although presenting an almost similar histological picture, there were a few irregular and fibroblastic nodules. Within such nodules the reticulin fibres were coarse and dense, with a little collagen (grade 2 fibrosis). The fibrosis steadily progressed, so that, by the 120th day, the lesions became partly acellular, and more collagen replaced the reticulin tissue (grade 3 fibrosis). From the 120th day to the 210th day there was very little change in the pathology, beyond grade 3 fibrosis (Fig. 7). By the 240th day the nodules were completely acellular and fully collagenous, with a slight tendency in places to conglomerate (grade 4 fibrosis). All the rats killed after this period showed areas of confluent fibrosis, which were acellular and wholly collagenous (grade 5 fibrosis, Fig. 11). The subpleural drift of the dust was more marked in this group of animals than in others. The presence of free dust cells, dust cell reaction in hilar lymph nodes, and the degree of pulmonary emphysema were similar to those in the previous group.

Cristobalite.—Cristobalite induced slightly more rapid and severe changes in the lungs of animals than those produced by the quartz (see Table 2). The lungs of the first animal that was killed at the thirtieth day showed moderately large aggregations of dust cells. Fibroblasts appeared in some and the reticulin fibres within were coarse and more compact

FIG. 5.—Rat lung 30 days after 50 mg. of tridymite dust: a nodule composed of rather loose reticulin fibres which are denser and thicker towards the centre (grade 1 fibrosis). (Silver impregnation, × 100.)

FIG. 6.—Rat lung 150 days after 50 mg. of amorphous silica dust showing one large nodule with coarse and compact reticulin and a few collagen fibres (grade 2 fibrosis). (Silver impregnation, ×65.)

FIG. 7.—Rat lung 150 days after 50 mg. of quartz dust showing almost fully collagenous silicotic nodules (grade 3 fibrosis). (Silver impregnation, × 65)

in the centre than at the periphery (grade 2 fibrosis, early, Fig. 4). Although the lesions were mainly in relation to vessels and bronchioles, some intra-alveolar and subpleural nodules were present. The lesions progressed rapidly to the next stage, and by the sixtieth day a large number of large stellate partly cellular nodules were seen. Densely packed coarse reticulin was transformed in places to collagen fibres (grade 3 fibrosis). The animals killed between this period and the 210th day did not show in their lungs any further progress than grade 3 fibrosis (Fig. 8). A rapid progress of the lesions was then observed. By the 240th day large areas of acellular, collagenous, and confluent fibrosis of grade 5 were seen. Within such fibrotic areas some alveoli remained patent and a few new blood vessels were formed. In between confluent fibrotic areas some degree of pulmonary emphysema was present. Similar lung pathology was seen in the rest of the animals (grade 5 fibrosis, Fig. 12) except one at 365 days, which showed only grade 2 fibrosis. The pleura seemed to be more involved in this lung, large areas of highly thickened pleura being seen. Free dust cells were seen in the lung fields of most of the animals. Emphysema was noted earlier in this experiment.

Tridymite.—This dust appeared to be the most active of all in producing pulmonary fibrosis. Extremely severe lesions (grade 5 fibrosis) were produced as early as the sixtieth day, and all the animals killed after this showed similar changes in their lungs (see Table 2). By the thirtieth day most of the dust cells were still scattered throughout the lung and there was an exudative reaction. The nodules were irregular, and fibroblasts appeared in the centres of some. Reticulin fibres were fine and loose in the periphery of such nodules, but the centres showed coarse and compact reticulin formation (grade 1 fibrosis, Fig. 5). These lesions progressed so rapidly that sections from the lungs of a rat on the sixtieth day showed completely acellular fully collagenous fibrosis. Almost all the nodules manifested a spreading character, encircling a bit of healthy lung tissue where emphysema was

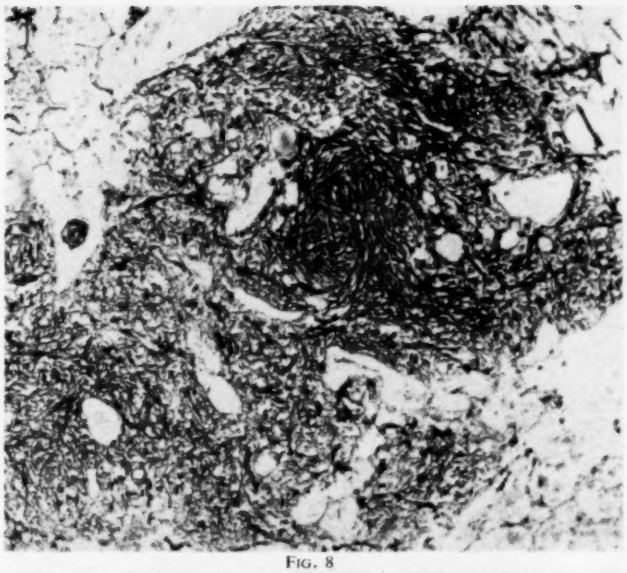

FIG. 8

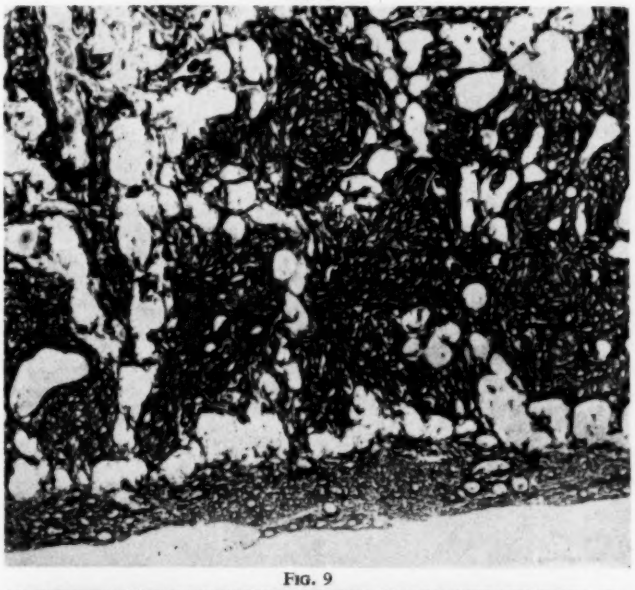

FIG. 9

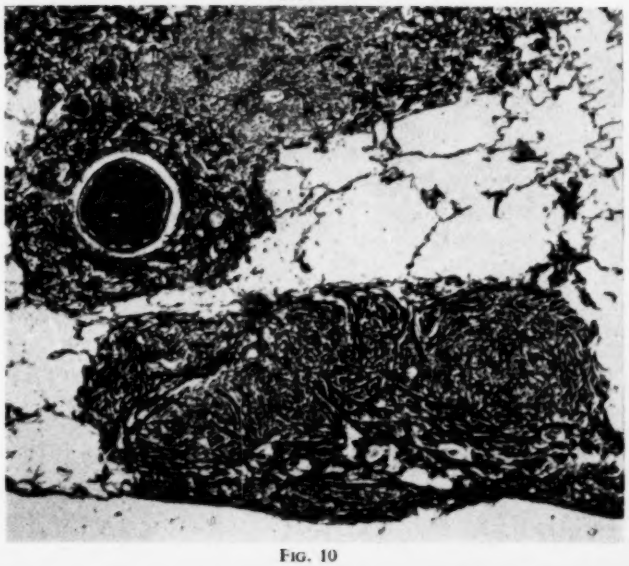

FIG. 10

FIG. 8.—Rat lung 150 days after 50 mg. of cristobalite dust showing almost fully collagenous nodules (grade 3 fibrosis). (Silver impregnation, ×65.)

FIG. 9.—Rat lung 60 days after 50 mg. of tridymite dust showing fully collagenous confluent nodules with patent alveoli within some of them and pleural thickening (grade 5 fibrosis, early.) (Silver impregnation, × 65.)

FIG. 10.—Rat lung 330 days after 50 mg. of amorphous silica dust, showing an almost fully collagenous subpleural nodule, pleural thickening and some degree of emphysema (grade 3 fibrosis). (Silver impregnation, × 40.)

FIG. 11.—Rat lung 330 days after 50 mg. of quartz dust showing fully collagenous and confluent fibrosis (grade 5 fibrosis). (Silver impregnation, × 40.)

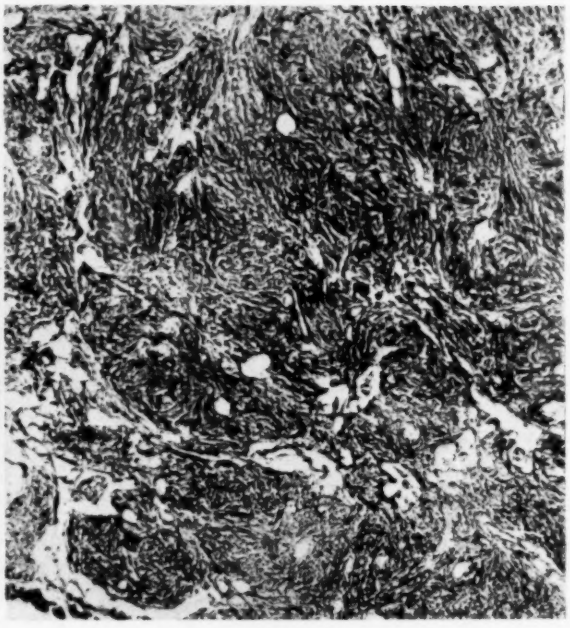

FIG. 13.—Rat lung 330 days after 50 mg. of tridymite dust showing fully collagenous confluent fibrosis of grade 5 involving the overlying pleura. (Silver impregnation, × 40.)

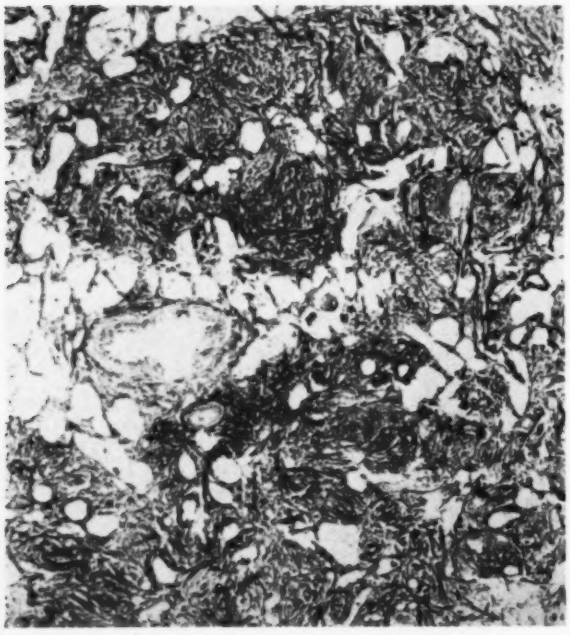

FIG. 12.—Rat lung 330 days after 50 mg. of cristobalite dust showing fully collagenous and confluent areas with patent alveoli within (grade 5 fibrosis). (Silver impregnation, × 40.)

seen (grade 5 fibrosis, early, Fig. 9). Formation of new blood vessels and central areas of necrosis were seen within some of the nodules. The pleura in most parts was thickened. All the animals killed subsequently showed similar changes ; and in some fibrosis involved a major part of the lung leaving very little healthy tissue (grade 5 fibrosis, Fig. 13).

Discussion

The results are best summarized by listing the shortest time intervals required to produce the various grades of fibrosis :

Form of Silica	Minimum Time (in Months) Required to Produce Fibrosis of Grades 2–5			
	2	3	4	5
Fused silica	2	7	No further change	
Quartz	2	3	8	9
Cristobalite ..	1	2	7½	8
Tridymite	1	1½		2

The four pure silica modifications all had very similar silica solubilities and size distributions, and were injected in equal amounts of 50 mg. corresponding to about 1,000 cm.^{2} of silica surface per rat. The resultant fibrosis varied considerably.

With fused silica there was no further progress beyond grade 3 within seven to 15 months.

Quartz and cristobalite acted similarly. Grade 3 lasted from two or three months up to about seven or eight months and there was regular progression to grade 5. The cristobalite acted perhaps slightly faster than the quartz, as all grades were reached about a month earlier.

The tridymite effect was spectacular. Grade 2 was reached after only one month, and grade 5 after two months. The fibrotic masses continued to grow, until in rats killed after 12 months there was hardly any normal lung tissue left.

These results suggest that the crystal structure of pure silica does influence the tissue reaction. Quartz, tridymite, cristobalite, and fused silica are built up from silicon-oxygen tetrahedra of equal size and shape. The tetrahedra share oxygen corners only. Each silicon is surrounded by four oxygens and each oxygen is bound to two silicons. The feature that varies is the arrangement of the tetrahedra in space, and the bond angles which two silicons make with the oxygen that is bound to both. The tetrahedra can be packed tightly, as in quartz which has a density of 2·65, or more loosely as in the other modifications which vary in density from 2·2 for fused silica to 2·3 for cristobalite. The arrangement is regular with a three-dimensional periodicity in the three crystalline modifications, and it is a random arrangement in fused silica. The crystal structures of cristobalite and tridymite are known in their main features but not in precise detail.

It is not possible to say why the different modifications act so differently, and in particular what causes the very strong reaction of the tridymite. A closer examination of a number of tridymite samples may give further information.

Silverman and Moritz (1950) made intraperitoneal injections of quartz and spherical fused silica into rabbits and found that the quartz gave a stronger fibrogenic reaction. They explained the difference by assuming that the quartz had a larger surface area. In view of Gardner's and our own findings this explanation is unconvincing, especially if it is remembered that the specific surface of their fused silica, as measured by a gas adsorption method, was actually over four times larger than the quartz surface.

In summarizing the evidence it can be said that there is reasonable qualitative agreement between the experimental results of Silverman and Moritz, of Gardner, and our own.

Vitreous silica is less active and tridymite much more active than quartz. Cristobalite is perhaps slightly more active than quartz.

Summary

Different forms of free silica, i.e. fused silica, quartz, cristobalite, and tridymite of high purity and equal size, were injected intratracheally into the lungs of rats to study any differences in the rate and severity of pathogenic reactions which they might produce. Of these, fused silica produced the least rapid pulmonary fibrosis, quartz the second, cristobalite the third, and tridymite was the most rapid in producing tissue reaction. In spite of their almost identical silica content, size distribution, and silica solubilities, the crystalline modifications acted more rapidly than fused silica and there were marked differences between the crystalline forms. It seems probable that tissue activity is somehow related to the crystal structure of the dust, but this cannot as yet be explained.

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SOME PSYCHOLOGICAL CONFLICTS CAUSED BY GROUP BONUS METHODS OF PAYMENT

BY

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The need for a high level of industrial output has given rise in recent years to a widespread discussion on wage incentives. Although no statistics exist showing the total number of workers in British industry who are paid by results, such figures as the Ministry of Labour has been able to collect indicate that the number is increasing. In October, 1951, just over a third of the workers at the 56,200 industrial establishments surveyed by the Ministry were paid on some system of payment by results, and in nearly all groups of industries the percentage of workers was higher than it had been in October, 1949 (*Ministry of Labour Gazette*, 1952). In a pamphlet giving the results of the 1949 inquiry the Ministry of Labour and National Service (1951) stated that wage incentive schemes, if well designed and suitable, " will benefit the nation as a whole and give mutual advantage and satisfaction to the employers and workers concerned " and advocated " a more general adoption " of such schemes. Thus official encouragement is now being given to the use of such schemes. This article presents some results of recent researches which indicate not only the difficulties of applying incentive payment to many industrial processes but also the often harmful effects on the morale and possibly on the health of the workers.

Many claims have been made that wage incentive schemes lead to increased production, but attempts to secure reliable evidence on this point have usually met with failure, since in practice it has proved impossible to isolate the effects of the " incentive " from those of other factors. For example, as the International Labour Office (1951) among others has pointed out, a subsequent rise in production may be largely due to " the work study which is required to enable a system of payment by results to function smoothly and successfully ". Many other variables also make it difficult to establish a causal as distinct from a temporal relationship. The aim of this article, however, is not to discuss bonus systems in general or to examine them in relation to their effect on production, but to summarize some of the main results of an inquiry into the attitudes of certain groups of industrial workers towards their group bonus methods of payment. Few scientific studies have yet been made of workers' attitudes to their systems of payment, nor has detailed consideration been given to the psychological effects of such schemes. The International Labour Office report already quoted mentions the danger that " if the task is set too high, or there is a low guaranteed minimum wage, the health, efficiency and morale of the workers may be adversely affected " (p. 178). As the following results will show, the task set and the wage guaranteed are only two of the many factors which may have these undesirable effects.

It is only by considering a system of payment from the point of view of the workers concerned that any appraisal can be made of the causes and nature of their reactions to it. The effectiveness of any external stimulus or " incentive " must depend very largely on the potential strength of the drives to action to which it is directed. Without some understanding of the motives and " ends " of the workers it is impossible to say how far a wage incentive provides stimulus and satisfaction. There are clearly great individual differences in the strength and constancy of the desire for money and there are differences also in the drives to attain other means to satisfaction. Workers' judgments of their systems, and even of their amounts, of payment are relative, not absolute, and the standards by which they estimate " good " and " bad " are still imperfectly known. It seems, however, that their attitude to their system of payment is largely, perhaps

mainly, determined by the degree to which the behaviour induced by the effort to earn more money conflicts or harmonizes with behaviour directed to other ends. If opposing drives are strong enough they may result not only in the workers' refusal to respond to the financial incentive but in a definite restriction of output. But whatever the outcome in terms of production, the conflicts tend to arouse feelings of anxiety and frustration that are manifested in a variety of psychological and physical symptoms.

Since both psychological and, to some extent, physiological factors are involved in the problem of methods of payment, it would seem that these are, or might profitably be considered, the concern of the factory medical officer as well as of the " production expert " and the management. It is not the " wage earner " but the whole man who goes to work, and the closeness of the relation between mental attitudes and physical health is becoming increasingly realized. Cases have come to the notice of the present investigator in which workers complaining of symptoms of fatigue and strain, which they attributed to working " on bonus ", have refused to consult their factory medical officer for fear that he would put them on a fixed wage job. The drop in the weekly wage that this change would entail would mean that one source of anxiety would be replaced by another and even more acute source. Apparently it did not occur either to these workers or to the medical officer that the latter might consider it within his duties to re-examine the payment system and possibly advise changes in the system rather than in the jobs of the workers. Lane (1936) has pointed out that in dangerous industries a system of payment which encourages " speeding-up " may greatly increase the number of cases of industrial disease. Even in industries which involve no serious hazards to health, however, the medical officer might do much to improve the general well-being and morale of the workers if he advised on the planning of systems of payment and supervised the workers in relation to them.

Scope of the Investigation

The inquiries from which the material here presented was gathered were made in the periods March, 1948, to March, 1949, and June, 1950, to April, 1951. The inquiries were undertaken for a variety of reasons but in all cases each worker involved was given a general interview covering all the main aspects of working life, including amounts and methods of payment. Only those workers who were paid on a group bonus system (386 men and 402 women) are dealt with in this article. In each factory the workers selected were either the total number on a particular operation or were a statistically random sample of a department or factory. Each worker was interviewed singly and in private, and was given an assurance that the interview would be regarded as confidential. It is not possible to give particulars here of the interviewing technique used. Briefly, this consisted of using both the " free " and the " controlled " methods in the same interview so that the person interviewed was encouraged both to talk spontaneously and also to answer certain pre-determined questions. Various devices were used to prevent or correct interviewer-bias. The interviews were voluntary but almost all the workers cooperated willingly and talked extremely frankly and fully. The percentage of refusals was 0·4, except in one department of about 90 workers where it was 10%, mainly owing to a rumour which could not be entirely dispelled that the investigators were psychiatrists. In all cases both the managements and the workers' representatives had approved the investigations and helped to facilitate them. The fact that the investigators were outsiders, from an independent research organization, helped to establish confidence and it is of some interest that the workers often showed themselves not only willing but eager to assist in a scientific inquiry from which they were told to expect no immediate and personal benefits. During the interviews the workers gave in some detail their reasons for liking or disliking the system of payment and finally were asked to assess their attitude to it on a five-point rating scale.

The workers were employed in five factories, in three of which a variety of articles were manufactured or processed. The main types of work carried out by the men were the making of parts of pre-fabricated concrete houses, engineering and building maintenance and repair work, the making or disposal of miscellaneous military equipment (details of which cannot be given here), and cigarette manufacture. Women were also engaged on the two latter types of work as well as on making clothing and pottery. The numbers in a payment group varied considerably, ranging from two, e.g., the operator and his woman assistant on a cigarette-making machine, to about 180, e.g., the total number in a department making pre-fabricated houses. All the workers were paid a fixed hourly rate and a bonus based on the relation of actual to expected time (determined by time-study) for the work done. The bonus of the maintenance workers was reckoned partly on their own work and partly on the total production of the factory.

TABLE 1
ASSESSMENTS OF ATTITUDES TO THE GROUP BONUS SYSTEM

(a) Men	Prefabricated Houses		Military Equipment		Factory Maintenance		Cigarettes		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Extremely satisfied	2	2·5	0	0·0	4	4·9	8	6·8	14	3·6
Satisfied	37	46·8	25	23·1	18	22·0	24	20·5	104	26·9
Neutral or divided	25	31·6	42	38·9	42	51·2	34	29·1	143	37·0
Dissatisfied	14	17·7	33	30·6	14	17·1	23	19·7	84	21·8
Extremely dissatisfied	1	1·3	8	7·4	4	4·9	28	23·9	41	10·6
Totals	79	99·9	108	100·0	82	100·1	117	100·0	386	99·9

(b) Women	Clothing		Military Equipment		Pottery		Cigarettes		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Extremely satisfied	0	0·0	0	0·0	0	0·0	4	1·6	4	1·0
Satisfied	27	34·6	11	22·0	2	8·7	84	33·5	124	30·8
Neutral or divided	27	34·6	14	28·0	5	21·7	89	35·5	135	33·6
Dissatisfied	24	30·8	17	34·0	16	69·6	62	24·7	119	29·6
Extremely dissatisfied	0	0·0	8	16·0	0	0·0	12	4·8	20	5·0
Totals	78	100·0	50	100·0	23	100·0	251	100·1	402	100·0

Some Results Obtained

Self-Assessments of General Attitudes to Method of Payment.—Table 1 shows the self-assessments, on a five-point rating scale, by the workers of their general attitude to their system of payment. It will be seen that the figures for the total numbers of men and women are very similar, about a third being extremely or moderately satisfied, a third being divided or neutral in attitude, and a third being dissatisfied. There are naturally differences between persons on different types of work, and a finer breakdown would show even greater differences, but it may be noted that the highest figure for satisfaction among the men is only 49·3% (pre-fabricated houses). In this particular instance it should be said that in one of the two factories concerned (employing 40 of the 79 men in this group) the men were able to earn an exceptionally high bonus, more than twice as much as any worker in other departments of the same factory. The outstanding difference among the women, although this was a small group, was the high proportion of pottery workers who were dissatisfied. This is an instance of the effect of introducing a bonus system into a newly-opened department in which methods of working were still largely experimental and in which both the supervisors and the workers were not experienced. Despite differences between different groups of workers, however, both the favourable and the unfavourable comments made were fundamentally very similar even if the frequency or emphasis varied. Even a broad analysis of these comments indicates not only some of the sources of strain but also the positive goals which the workers desire to reach.

Favourable Comments on Group Bonus System of Payment.—Since the main subject of this article is the conflicts arising from the bonus system of payment, the favourable comments will be mentioned only briefly. It should, however, be said that reasons for liking the system were given by the majority of both men (73·1%) and women (67·2%), including many of those whose general attitude was unfavourable. A considerable minority, about a fifth of both men and women, stated emphatically that they liked nothing whatever about the system. Two types of comment accounted for nearly all the favourable remarks and were made with almost equal frequency. First, some workers spoke of the personal satisfaction of having an opportunity to earn more money. However, many of these workers qualified their statements by saying that without the bonus payment they did not earn an adequate living wage. As one man said, " I only like it because it makes your wages up. Without bonus the wages are not enough to cover costs and it's dreadful for a married man rearing children." Secondly, some spoke of the social advantages of group bonus methods of payment, saying that it encouraged everyone to work and do a fair share. A typical comment was, " It makes everyone more amicable. This way you have no strong men and weak men but each man works to his own capacity and earns a full bonus." The implication of the above remark is that it is just to reward a man according to his willingness rather than according to his performance. It is a different attitude from that of the much smaller group (7·5% of men and 9·0% of women) who said that it was " fair to be paid for what you do ". However the relative infrequency of the

latter comment may have been partly due to the fact, to be discussed later, that very few workers were able to see any clear relation between effort and reward.

The amount of the average weekly wage, including bonus earnings, affected the general attitude of the workers to the system of payment, those who were satisfied with their wage tending to be less critical of the method by which they had obtained it. However, although there were variations according to type of work, both men and women were far more satisfied with amounts than with methods of payment. Only a small minority of the total men and women (11·7% and 16·2%) thought that their wages were poor, although far larger proportions (32·4% and 34·6%) were definitely dissatisfied with their system of payment. One factor determining a worker to call his wages " medium " rather than " good " was the unpredictable fluctuations of the bonus, commented on in this connexion by 17·5% of men and 22·7% of women.

TABLE 2

NUMBER OF PERSONS EXPRESSING THREE TYPES OF CONFLICT ARISING FROM THE GROUP BONUS SYSTEM

(*a*) Men	Prefabricated Houses		Military Equipment		Factory Maintenance		Cigarettes		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Conflict between theory and practice ..	29	36·7	80	74·1	43	52·4	86	75·5	238	60·1
Social conflicts	14	17·7	77	71·3	38	46·3	56	47·9	175	45·1
Personal conflicts	16	20·3	34	31·5	12	14·6	54	46·2	116	30·1
No criticisms	34	43·0	17	15·7	21	25·6	16	13·7	88	22·8
Total in group	79	—	108	—	82	—	117	—	386	—
(*b*) Women	Clothing		Military Equipment		Pottery		Cigarettes		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
Conflict between theory and practice ..	56	71·8	38	76·0	19	82·6	162	64·5	275	68·4
Social conflicts	50	64·1	36	72·0	10	43·5	97	38·6	193	48·0
Personal conflicts	7	9·0	9	18·0	12	52·2	51	20·3	79	19·7
No criticisms	13	16·7	8	16·0	1	4·3	52	20·7	74	18·4
Total in group	78	—	50	—	23	—	251	—	402	—

Unfavourable Comments on Group Bonus System of Payment.—Adverse comments were made by 77·2% of the men and 81·6% of the women, including some of those who assessed their general attitude in one of the two top categories of the rating scale. These comments were very varied but all the specific and sometimes very localized grievances they expressed may be regarded as indications of three main types of psychological conflict. The most frequent conflict may be termed that between expectation and result, or between theory and practice ; this arose when the worker was prevented, by causes apparently or actually largely outside his control, either from determining his own rate of working or from receiving an understandable and commensurate reward. Secondly, a conflict might arise between the desire of the individual or the group to earn bonus and the desire to maintain or create good social relationships. And thirdly, the individual might find that the behaviour induced in himself by the effort to reach or exceed his target was at variance with his personal standards of health and conduct.

The number of workers who criticized their system of payment on one or more of these three grounds, together with the number who had no complaint, is shown in Table 2.

Table 2 shows that even in the most satisfied group of workers (the men making prefabricated houses) a majority made adverse comments, of which the most frequent were those indicating the discrepancy between theory and practice. There are differences, as would be expected, between the groups and between the sexes, but a full discussion of these would involve giving details of local circumstances for which space is not here available. Some examples will be mentioned later.

A broad analysis of the comments which have been grouped into these three categories is made in Table 3, which shows the frequency of the main types of criticism within each category.

Conflict between Theory and Practice.—Criticisms considered to reflect this type of conflict were made by 60·1% of the men and 68·4% of the women and accounted for just over half of the total number of critical comments. The most frequent group of comments included in this category referred to the apparent lack of connexion between bonus earnings and effort. Many workers, men and women, felt

TABLE 3

NUMBER OF WORKERS MAKING CRITICISMS* REVEALING EACH TYPE OF CONFLICT ARISING FROM GROUP BONUS SYSTEM

	Men		Women		Total	
	No.	%	No.	%	No.	%
Conflict between theory and practice	238	60·1	275	68·4	513	65·1
Bonus apparently not related to effort	151	39·1	191	47·5	342	43·4
Timing or rate-fixing unjust	116	30·1	156	38·8	272	34·5
Management unreliable or suspect	52	13·5	66	16·4	118	15·0
Social conflicts	175	45·1	193	48·0	368	46·7
Between groups	123	31·9	101	25·1	224	28·4
Within bonus groups	62	16·1	113	28·1	175	22·2
Unspecified " bad feeling "	11	2·8	16	4·0	27	3·4
Personal conflicts	116	30·1	79	19·7	195	24·7
With concern for health and safety	74	19·2	46	11·4	120	15·2
With own code of behaviour	61	15·8	44	10·9	105	13·3
Total number of persons making criticisms	298	77·2	328	81·6	626	79·4
Total number in group	386	—	402	—	788	—

* Many workers made more than one criticism in each category.

both irritated and anxious at the fluctuations in their weekly wage. In some cases these fluctuations were, in fact, large enough to have a considerable effect on the household budget (and occasionally led to trouble between men workers and their wives).* However, complaints of the unpredictability of the bonus were often more vehement and frequent than the actual variations in amounts earned seemed to warrant and they often seemed to arise from a feeling that the assumed basic principle of " payment by results " was, or appeared to be, violated in practice. In theory, the system should give them rewards proportionate to their efforts but in practice their earnings often seemed to bear little relation to effort or even to output and seemed determined by factors that were outside their control and often only dimly understood. From workers on many types of jobs came complaints that " the bonus just goes up and down and you never know why " and " It's just luck. There's no sense in it ". In such workers the bonus system aroused a sense of injustice or of helpless bewilderment ; as one man put it, " It gives you neither uplift or cover ".

There were many and varied reasons why so many workers found it impossible to see a clear relation between effort and reward. The constant changes of jobs, some of which carried no bonus at all, in the military equipment departments, were an obvious and outstanding example. However, even on jobs where the workers were continuously employed and the flow of work fairly steady, estimation of the bonus to be expected was complicated by numerous factors, such as the various allowances (for machine breakdowns, etc.), the changes in quality of materials, and changes in the composition and size of the group. On one such job a woman said, " We get allowances for breakdowns and things, but we never know exactly how much. And then they take off for rejects. I think you ought to know how much work you've done and what you'll be paid for it but nobody bothers to explain. I don't like the bonus at all, but, to be honest, I might like it better if I understood it."

Another type of situation in which some workers felt that their own capabilities and intentions had little effect on their earnings was that in which the amount of work that it was possible to do was controlled by outside circumstances. For example, on some jobs the amount of material allocated to the workers was determined by production planning, which itself was closely and immediately dependent on orders received by the firm. In one tobacco factory the fluctuations of an individual worker's bonus would reflect the seasonal variations in the demand for cigarettes. On other jobs the work available was determined by the output of workers on a preceding operation or by the requirements of workers who had to be serviced. One man, for instance, whose task was to feed material into a group of machines, said, " The basis of bonus is supposed to be incentive. But we have none because we rely on others. We have no control as they reckon our bonus on the number of machines that are running." Differences in bonus earnings between two groups, one dependent on the other for the amount of work supplied to them, sometimes caused

* In one military equipment department the records of the 27 men interviewed showed that in an eight-week period 16 of them received no bonus at all in at least one week, that bonus earnings ranged from 2*s*. 4*d*. to £1 14*s*. 0*d*. and that for 10 of the men the fluctuations were £1 or more during the period. In a tobacco department, where conditions were more stable, the bonus earnings of a group of 23 machine operators ranged from 7*s*. 9*d*. to £1 7*s*. 9*d*. in a 12-week period, although for 15 of the men the fluctuations in their weekly wage were not greater than 15*s*. In both cases the causes of the large differences in earnings were, according to the supervisors, mainly due to the variations in required production dictated by external conditions over which they themselves had no control.

very bitter feeling, as shown by the woman tobacco worker who said, " The bonus is the most abhorrent thing that ever came out. It puts all the workers against each other because different groups get different bonus even if they handle the same work. There's no justice in it at all."

Another kind of limitation on human effort and speed of working was that set by the fixed pace of a machine or process. For instance, the operators on cigarette-making machines could affect their bonus only by ensuring that machine faults were not leading to spoiled work or by forestalling or shortening machine stoppages. The main reason for machine stoppages was minor breakdowns or need for adjustments, and as it was at such times only that much demand was made on the skill and judgment of the operators, many of them felt that the bonus was in inverse proportion to their effort. As one man said, " The better your machine, the less you have to do and the more money you get ". Since these machines were delicate and complicated, many operators felt that their bonus was largely dependent on the " luck " of breakdowns, for they could not compensate for any loss of running time by putting on a spurt. This led many of them, as also many workers on other types of work, to wish for a daily and not a weekly bonus. As one said, " You learn that you can never say to the wife that you'll work extra hard, say to buy something for the house. You may run into trouble at any time, and you'll never get her to realize that and she'll just think you've been lazy ".

The difficulties in seeing a clear relation between effort and reward indicate a serious weakness in bonus schemes in many industrial situations. However, dissatisfaction about the unpredictability of the bonus tended to be more intense on the very jobs in which the relation between personal effort and output seemed to be closest. In the large groups, such as those comprising a whole department of perhaps over 100 workers, the workers accepted the fact that no individual could expect to predict the weekly bonus or to know how far his own work had contributed to it. Most of them, however, felt that this disadvantage was outweighed by the comparative steadiness of a bonus paid on a large group and by the social harmony resulting from the absence of differences in earnings within the department. The small groups, on the other hand, expected to see a direct relation and often thought that this relation was closer and simpler than was in fact the case, and so they experienced disappointment and frustration. The tendency for satisfaction to increase as the size of the group increases is not, of course, incompatible with the findings of research workers, such as Mace (1935) and Mackworth (1950), who have shown that efficiency of performance is affected by knowledge of results and the ability to measure success in attaining a given target. It suggests that misconceptions about the preciseness and personal nature of the target may lead both to ill-feeling and a weakening of the incentive.

The number of workers who spoke of the complicated method of calculating bonus as a disadvantage of the system was relatively small. However, in reply to a direct question on this point, under a third of the men and only 6·5% of the women said (sometimes clearly mistakenly) that they thought they understood it. The inability to check the accuracy of the weekly wage was, however, of less importance to most workers than their inability to estimate their daily progress. A few men brought slide rules to the factory and checked to see if their own calculations tallied with those of the wages department, but most workers were content with much simpler methods. One woman, for instance, said, " We compare our pay slips to see if all the groups have got about the same, and if they haven't we ask them to explain why. Not that we're much the wiser for it, but it lets them know we notice." In any case, most workers were, as one said, " no clerks " and found " all these decimals and per cents. just Dutch ".

The comments that the timing or rate-fixing were unjust and that the management were unreliable or suspect are somewhat different in character, since they imply criticisms not of the payment system itself but of the ability or intentions of those responsible for devising and administering it. Claims that the " time-study men " gave inadequate allowances for such matters as breakdowns or variations in machines or materials were made, though with varying frequency, in all departments. They were sometimes projections of a dissatisfaction that was not clearly understood, and the " allowances " or the " standards " were blamed because the workers felt strongly that someone or something must be responsible for the insufficiency or variability of their bonus. As one woman said, " When we don't get the bonus we think we should, we sometimes blame the machines or the allowances, sometimes the other girls and sometimes the foreman. It just depends how we feel. But we never really know." In one factory, however, there was a general suspicion that the management deliberately set any new bonus standard too high, so as to allow for bargaining. A worker in this factory said, " Around and around goes the same old circle, 'Too high'—'Not too high'. Eventually, after months, some compromise is reached. Then production goes sky high to make up for lost bonus, and the management

think they were right after all." Apart from criticisms of the standards set, there were also some complaints of indirect or direct rate-cutting if a too high output had been reached. In one clothing factory when the output of any line was too high (in relation to other lines) the management " readjusted " the team so as to include in it some less efficient workers. This caused resentment against the management and also social conflict among the women, since the speed of a line was necessarily that of the slowest worker. A group of men tobacco workers alleged an unfair rate-cutting some two years previously and since that time had imposed their own ceiling on production; and several workers in a military equipment department made remarks such as, " If you do too well the overlooker will say something to you, so that you won't have to have your rate cut or be moved."

Although, in the opinion of the investigators, cases of deliberate " twisting " by the time-study engineers were not common in these factories, it should be noted that in no factory was the setting of bonus standards preceded by any thorough and competent motion study. Even the casual observer might notice many examples of inefficient and wasteful methods of working. Some of the workers themselves commented on these and said that they thought it better to continue in these methods than to risk a re-timing of their jobs.

Social Conflicts.—The social conflicts arising from or attributed to the bonus system were in many cases the almost inevitable accompaniment of the various inequalities in opportunity already referred to and most of the comments on conflicts between groups were of this type. The word " conflict " in the sense here used does not necessarily imply personal hostility but rather a sense of division. In a number of cases, workers on the " good " jobs spoke of feelings of discomfort and sometimes almost of shame since their " luck ", as they termed it, tended to create a social barrier between them and the less fortunate. One said, " It's especially wrong for me, being a shop steward. I was really much happier when I was on a bad job ". The workers' comments showed that their wish for social harmony and for justice was sometimes frustrated by circumstances resulting from the system of payment, and, in other cases, that it came into conflict with the individual's desire or need to earn as much as he could irrespective of whether his rewards were due to merit or to chance. A small proportion of both men and women spoke of definitely hostile competitiveness between groups, particularly where a number of small groups were all engaged on similar work. In one such department in a tobacco factory the workers themselves had attempted to prevent this jealousy by refusing to agree to the production study engineer's proposal to post up the weekly output of each machine, and they had created a social code by which it was " not done " to try and discover another man's earnings.* Despite this, envy and jealousy existed and men watched their neighbours. There were sometimes open quarrels but envy was not always entirely of money, which might also be important as a symbol of superior skill or personal worth. As one man said, " If I'm having trouble with my machine and I see the man on the next machine doing well I can't help thinking ' He's a better man than me ' even if I know he isn't." Among these machine operators there was a strong wish to have their bonus system abolished, but the management firmly refused to do this, fearing a big drop in output. One of the men remarked, " You see, the management don't trust us to do a fair day's work, even though most of us have been here for years. They think we won't do anything except for money, and they're not interested in us but only in what we turn out." This feeling probably contributed towards making the poorer or less fortunate workers consider themselves personally inferior, but in this department as elsewhere there were some whose wish for dominance and superiority was given a means of expression if not positively encouraged through the system of payment.

Conflict within the groups arose mainly from differences between individuals in their willingness or capacity to work. Proportionately more women than men complained of laziness in others in the team, though it seemed that in some cases the word " lazy " was used by girls to describe someone whom they disliked for general or quite other reasons. In some groups of women the desire to earn bonus was often and apparently easily defeated by purely social motives. For instance, on one line in a clothing factory some girls admitted that they did not try to reach their target because they disliked their woman overlooker and " you don't feel like working if they (i.e. the supervisors) don't care." On another line one girl said that she had " said something to upset some of the girls " and so they had interfered with her machine. She added, " I've been off work for a week and it's only through worrying about the girls." Since the jobs on the line were interdependent any breakdown affected the whole team, but apparently the satisfaction of revenge was greater than that of money. The

* A similar code, most rigidly adhered to, existed in a social group of women individual piece workers in another tobacco factory.

comments on differences in capacity to work, although not very numerous, were often very emphatic. Resentment against the older, less fit or less competent members of a group was not common although many workers stressed the importance of having a homogeneous team, both personally and in capacity. Some workers, both men and women, considered that the social disunity caused by the bonus system was its greatest disadvantage and went so far as to say that, on this account alone, it was " evil " and produced " tragic results " and had " made more enemies than time can tell ".

Personal Conflicts.—The comments grouped under the heading of " personal conflicts " are those in which the individual considers the bonus system purely in its effects on his own attitude of mind or health of body. Complaints that the bonus led to feelings of strain or exhaustion were made by 19·2% of men and 11·4% of women. Comments on physical fatigue came mainly from workers in certain tobacco departments, in which conditions were hot and humid, and from the men making prefabricated houses. In the former case the complaints were often accompanied by expressions of anxiety that increasing age would soon make the present speed of working impossible. In the latter a number of the men were already 60 years old or more and felt driven too hard by the speed set by the group and, as one said, " by being determined not to let them say that we are on their backs ".

Nervous strain, rather than physical fatigue, was experienced by some of the machine workers. One of them said, " The strain is hard to explain to a lay person. The machines are almost human in their cussedness, and the strain is all increased by the bonus system, which accounts for 75% of it. The only thing to like about the bonus system is the money. Apart from that I hate the sight of it. It makes you a slave to the machine and the allowances are not adequate or fair." Another man, on a different type of machine, said, " It's the ruin of men's health, physically and mentally. When the bonus came on I worked so hard that I got pleurisy, with the sweating and then catching cold. Since then I've not bothered, for health is more important. At the moment I'm washing walls down, not on bonus, and have a nice relaxation of mind. They've a dozen or so of us employed on this and they're all cheerful and singing. It's because they're not on a bonus machine, though they don't realize it themselves." Another, aged 31, said, " In a few more years I shan't be able to keep at the rate needed. I don't know how some of the older chaps manage, because when I go home I'm finished. I flop in a chair and have no energy to lead my own life."

It is, of course, possible to argue, as did the time-study engineer of some of the workers quoted, that such comments indicate the " success " of the incentive. However, apart from the question as to whether this might not be a short-sighted point of view, there can be little doubt that some workers suffered severely from what they termed " nervous tension " and were apprehensive of becoming unable to continue their present jobs. Such workers often made the task of supervision difficult, one departmental manager describing his machine operators as " extraordinarily difficult to handle, touchy and liable to flare up over any trifle ", while another manager said that three-quarters of his time was spent in dealing with complaints about the bonus system.

The most frequent comment under the heading of conflict with " own code of behaviour " referred to the struggle between the desire for speed and the desire for quality. Quite apart from the effect that " rejects " had in lowering the bonus, the turning out of work that was not as good as it might have been was disliked and resented by some workers. On some of the jobs the product went through the hands of examiners before being passed on for the next process but in others the workers themselves acted as examiners. In the latter case workers sometimes gave way to the temptation to pass work that was of doubtful quality, especially if faults might plausibly be attributed to poor materials, although they might feel guilty in doing so. In the military equipment departments some workers admitted to breaking the safety regulations and others were very emphatic that it was " all wrong " to tempt them to take risks with articles which might be dangerous to the users as well as to the makers.

Various devices were used in the factories investigated to prevent the workers from working at a speed likely to prove deleterious to quality. One worker described his management as " trying to have it both ways and always dissatisfied because they won't realize that this is impossible ". These devices, however, often failed to take effect because the workers did not understand them. For example, on a group of machines in a cigarette factory, the management set a ceiling on daily production and stated that output in excess of this was not to be counted for bonus payment. The women resented this ceiling on the grounds that " I always thought the idea of a bonus system was that you could earn as much as you like " and also because they found it

extremely difficult to know when they had reached the prescribed limit and so often did more work than they were paid for.

The comments made by a few workers that bonus was " against Trade Union principles " referred to the traditional objections that payment by results led to unemployment and to exploitation. In some of these, and also in some of the remarks about the bad effects of bonus on character, the objections were primarily on ethical grounds. While it is true that what might be termed moral judgments were implied also in many of the remarks previously discussed about the injustice or enmity caused, here they were explicit and were expressed in phrases such as, " It makes you hard when you would not be normally. It brings out the worst in you ", " It sets men against each other and is an evil thing ", and, " It encourages you to be too kind to yourself when you are booking your stoppages ".

Summary

Some results of an investigation into the attitudes of 386 men and 402 women towards group bonus methods of payment are described. The workers' self-assessments of their general attitude to this system of payment showed that about two-thirds of the total number were either definitely dissatisfied with it or were neutral or divided in opinion. Although proportions varied in different types of work, in only one group did as many as half the workers express themselves as satisfied. The main reasons given for liking the system were that it increased earnings, many workers saying that without it they would not earn a living wage, and that group payment had various social advantages. About 80% of the workers made some criticism of the system and the criticisms indicate that the workers tended to have very similar standards of judgment, despite the great differences in their jobs and circumstances.

An analysis of the reasons given for disliking the system shows that it aroused three main types of psychological conflict. First, the desire to earn more money, stimulated by the assumption that reward is dependent on effort, is often thwarted both by the difficulty of observing the relationship and by the influence on the bonus of many factors outside the control of the worker. This leads to a sense of injustice, which may be expressed in aggressive behaviour or in feelings of helplessness. Secondly, and closely connected, are the social conflicts arising within or between the payment groups. Thirdly, workers may experience personal conflicts in that they feel impelled to act in a way that is opposed to their concern for their health, their standards of workmanship, or their ethical code.

These conflicts are basically psychological and are largely emotional rather than intellectual in nature. They tend to arise when bonus systems are introduced in unsuitable circumstances and without due knowledge of or regard for the existing motives and scale of values of the workers.

There is considerable evidence that these systems of payment cause feelings of physical and, more often, mental strain. Complaints of strain are apparently seldom referred to the factory medical officer, either because workers consider that conditions of payment, unlike physical working conditions, are outside his sphere or because they fear he might order them to be moved to a job which carries no bonus and which they cannot afford.

The factories here investigated all employed medical officers and had well equipped surgeries and welfare departments. In no case did the medical officer take any part in advising on the systems of payment, which were usually left entirely to the production study engineers. These engineers tended to base their theories and practices on inadequate and often wholly unwarranted psychological assumptions about " the worker ". It is suggested that there is urgent need for systems of payment to be regarded primarily as matters affecting the health and morale of workers and, therefore, in their broad principles, as the concern of the industrial medical officer. Many of the objections raised to them might be obviated if the general policy were jointly framed by management, personnel officers, and medical officers, and if the production engineers were regarded as technical experts to carry out this policy. The effects of systems of payment present an almost unexplored field for students both of social psychology and social medicine.

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EMOTIONAL STABILITY IN COLLIERY WORKERS

BY

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This paper reports the results obtained by using a small battery of objective tests of emotional stability in the clinical examination of a group of colliery workers. The main object of the investigation was to establish the incidence of rheumatic conditions among selected samples of office, maintenance, and underground workers at a particular colliery and these results have already been reported in this journal (Kellgren and Lawrence, 1952).

Population Studied

The total number of men involved in the present study was 184 of whom 76 were working underground. All the men were within the age-range 40 to 50 years.

Tests

The battery, taking about 30 minutes to administer, contained the following tests :—

Word Connection List (Crown, 1947, 1952).—The score is the number of " neurotic " responses marked in a list of 50 items consisting of a stimulus word followed by two response words.

Maudsley Medical Questionnaire (Eysenck, 1947, 1952).—A 40-item neuroticism inventory constructed empirically in terms of responses obtained from several thousand " normal " and " neurotic " subjects.

Leg Persistence Test (Eysenck, 1947).—This is scored as the number of seconds the seated subject is prepared to hold his leg fully extended above a nearby chair of the same height.

Annoyances List (Bennett, 1945).—The subject is asked to mark items which tend to annoy him from a list of 60 common annoyances.

Finger Dexterity Test (United States Employment Service, 1947).—This test is Section O (Assembly) from the General Aptitude Test Battery. The task involves the transfer of rivets from the upper to the lower half of a board, threading a washer on to the rivet en route.

There was evidence that each of these tests was capable of distinguishing significantly between groups of subjects (mainly soldiers) classed by psychiatrists as " neurotic " or " emotionally unstable " and other groups regarded as " normal ". Factor analyses of batteries of such tests, including those listed above, had shown that they provided loadings on a general factor which may be called " emotional instability ".

Statistical Treatment of Results

The range, mean, and standard deviation of raw scores for each test is shown in Table 1. These scores were converted into normalized percentile scores, using nine groups to facilitate Hollerith

TABLE 1
RAW SCORES

Test	Range	Mean	Standard Deviation
Word Connection List ..	1–32	14·3	7·0
Maudsley Medical Questionnaire	0–32	9·86	7·0
Leg Persistence Test (sec.) ..	13–270	94·2	59·39
Annoyances List	1–60	33·8	12·96
Finger Dexterity Test	11–39	25·05	3·46

TABLE 2
INTERCORRELATION MATRIX

Test	Scoring Direction	1	2	3	4
Word Connection List ..	High	—	—	—	—
Maudsley Medical Questionnaire	High	0·128	—	—	—
Leg Persistence Test ..	Short	0·086	0·221	—	—
Annoyances List	Many	0·040	0·139	0·103	—
Finger Dexterity Test ..	Low	0·148	0·013	0·156	−0·009

An r of 0·147 is significant at the 0·05 level.

TABLE 3
FACTOR* LOADINGS

Word Connection List	0·33
Maudsley Medical Questionnaire	0·42
Leg Non-persistence	0·52
Annoyances List	0·23
Finger Non-dexterity	0·25

*The factor accounts for 13·4% of the variance.

processing. Product moment correlation coefficients were then computed between each pair of variables. The resulting matrix (shown in Table 2) was then factor-analysed by Burt's simple summation method. A single factor was extracted for which loadings are shown in Table 3. The residual matrix is shown in Table 4, from which it will be observed that no

TABLE 4
RESIDUAL MATRIX

Test	Word Connection List	Maudsley Medical Questionnaire	Leg Persistence Test	Annoyances List	Finger Dexterity Test
Word Connection List	(0·069)	−0·012	−0·087	−0·035	0·064
Maudsley Medical Questionnaire	—	(0·054)	0·004	0·045	−0·092
Leg Persistence Test	—	—	(0·071)	−0·014	0·026
Annoyances List	—	—	—	(0·069)	−0·065
Finger Dexterity Test	—	—	—	—	(0·067)

S.E. of Zero r = ± ·076

residual greatly exceeds the standard error of a zero correlation (+ 0·076). The five tests provide a multiple correlation coefficient with the factor of 0·686 using Aitken's pivotal condensation method. The normalized percentile scores for each test were therefore combined to give a weighted composite score for each individual, referred to hereafter as the " emotional instability score ". This process gives each man a score between 1 and 9 which locates him *within the group* studied. The cutting points for these scores are shown in Table 5. For example, if an individual has a score of 2, he will be found among the 20 (10·7%) *most* emotionally stable, while another man with a score of 6 will be found among the 74 (40·2%) *least* emotionally stable, and a third with a score of 5 among the *middle* 36 (19·6%).

Findings

The examining physician in the rheumatism project, though not a psychiatrist, undertook to assess each man's mental state on a four-point scale without knowledge of the test results. This was later reduced to three by combining two adjacent categories. The final categories were described by him as follows :—(1) Positive mental health, well integrated (39·6%) ; (2) doubtful, though no definite signs or symptoms (49·7%) ; (3) presenting signs or symptoms of mental ill-health (10·7%).

The product moment correlation between this simple rating and the nine-point emotional instability score based on the objective tests is + 0·3, which is significant (P = 0·001). The full distribution of the emotional instability scores against the physician's categories is shown in Table 6. (The

TABLE 6
COMPARISON OF PHYSICIAN'S CATEGORIES WITH NORMALIZED PERCENTILE SCORES (EMOTIONAL INSTABILITY)

Physician's Categories	No. of Cases*	Emotional Instability Scores								
		1	2	3	4	5	6	7	8	9
(1) Well integrated	70	5	7	12	14	10	10	8	3	1
(2) Doubtful	88	3	5	9	13	19	19	9	5	6
(3) Signs or symptoms	19	0	0	0	3	6	1	4	4	1
Totals	177	8	12	21	30	35	30	21	12	8

*Seven cases seen by the psychologist were not seen by the physician, thus reducing the total to 177 when comparing results.

totals will serve as a reminder that while the former scores have been normalized the latter have not, a point which must be borne in mind during the ensuing argument.) The first thing to strike the eye is the group of zero entries in the bottom left-hand corner of the table, as one would expect from the existence of the significant correlation already quoted. However, it is also apparent that there is far from perfect agreement between the two associated measures, as again would be expected from so small a coefficient as +0·3. In order to simplify evaluation of the data, Table 7 shows the result of dividing the emotional instability scores for each of the physician's categories at the mid-

TABLE 5
NORMALIZED PERCENTILE SCORES

	1	2	3	4	5	6	7	8	9
Number in each category	8	12	22	32	36	32	22	12	8
Percentage in each category	4·1	6·6	12·1	17·4	19·6	17·4	12·1	6·6	4·1
Ascending cutting points (No.)	8	20	42	74	110	142	164	176	184
" " " (%)	4·1	10·7	22·8	40·2	59·8	77·2	89·3	95·9	100·0
Descending cutting points (No.)	184	176	164	142	110	74	42	20	8
" " " (%)	100·0	95·9	89·3	77·2	59·8	40·2	22·8	10·7	4·1

TABLE 7

COMPARISON OF PHYSICIAN'S CATEGORIES WITH UPPER AND LOWER HALVES OF EMOTIONAL INSTABILITY SCORES

Physician's Categories	Emotional Instability Scores		
	Relatively Stable Half	Relatively Unstable Half	Total
(1) Well integrated	43 (70)	27 (0)*	70
(2) Doubtful	39 (18)	49 (70)	88
(3) Signs or symptoms ..	6 (0)	13 (19)	19
Total	88	89	177

*Figures in brackets denote " expectations " (see text).

point, i.e., totals for scores 1 to 4 plus one-half of 5 form the " relatively stable " half, while totals for scores 6 to 9 plus one-half of 5 form the " relatively unstable " half. If there had been *perfect* agreement between the physician and the test-battery, one would expect to find *no* cases of the physician's category 1 (" definitely healthy ") in the " relatively unstable " half of the psychometric scores, and similarly *no* cases of the physician's category 3 in the " relatively stable " half. These expectations have been entered in parenthesis in the appropriate sections of the table, and the other " expected " figures shown are of course obtained by subtraction. The total number of cases in the full sample (N = 177) which fall in the " wrong " cells is 54 (27 + 21 + 6) or 30·5%. It is evident that much of this lack of agreement occurs because the normalized test-battery scores classify many people as " relatively unstable " to whom the physician gave a clean bill of mental health ; there are fewer cases of the opposite error, where the physician was uneasy about people who fall in the " relatively stable " half of the psychometric scores. (In Table 8 it can be seen that this is true within each of the four occupational groups making up the total sample.)

The emotional instability score is uncorrelated with a diagnosis of rheumatism in the lumbar spine or undetermined pain of lumbar and sciatic distribution, or with rheumatic symptoms in the same areas during the previous five years.

When the sample is classified as sedentary (21%), manual surface workers (24%), workers spending part of their time above ground and part below (13%) and underground (42%), a significant relationship is found with the distribution of emotional instability scores ($\chi^2 = 28{\cdot}33$; df = 12, $P < 0{\cdot}01$, $> 0{\cdot}001$). If the occupational classification can be regarded as a continuum from office-stool to coal-face, then a significant contingency coefficient of 0·36 is found between the two variables. This means that as one proceeds along the continuum in the given direction emotional instability as measured by the test-battery *increases*. In case the actual nature of any particular test might be largely responsible for this overall result due to extraneous

TABLE 8

COMPARISON OF PHYSICIAN'S CATEGORIES WITH UPPER AND LOWER HALVES OF EMOTIONAL INSTABILITY SCORES BROKEN DOWN FOR OCCUPATIONAL GROUPS

Occupational Groups	Physician's Category	%	Emotional Instability Scores			
			Relatively Stable Half	Relatively Unstable Half	Total	% Unstable Relatively
I : Sedentary	1	43·3	11 (16)	5 (0)*	16	
	2	45·9	12 (9)	5 (8)	17	
	3	10·8	2 (0)	2 (4)	4	
		100·0	25	12	37	33·4 (50)
II : Manual (Surface)	1	45·2	13 (19)	6 (0)	19	
	2	52·4	10 (4)	12 (18)	22	
	3	2·4	0 (0)	1 (1)	1	
		100·0	23	19	42	45·2 (50)
III : Surface + Underground	1	43·5	6 (10)	4 (0)	10	
	2	47·8	3 (1)	8 (10)	11	
	3	8·7	2 (0)	0 (2)	2	
		100·0	11	12	23	52·2 (50)
IV : Underground	1	33·3	13 (25)	12 (0)	25	
	2	50·7	14 (4)	24 (34)	38	
	3	16·0	2 (0)	10 (12)	12	
		100·0	29	46	75	61·3 (50)
Totals			88	89	177	

*Figures in brackets denote " expectations."

systematic differences between underground workers and surface workers, detailed examination of the score distributions was made for each of the five tests. The trend is observable in every case, despite the differing nature of the tests. This trend can readily be examined in Table 8, though the small totals in certain categories give rise to unstable percentages to which little value should be attached. It is, however, quite clear that the percentage of cases falling in the " relatively unstable " half of the psychometric scores steadily increases from 33·4 in Group I (sedentary) to 61·3 in Group IV (underground). It should be remembered that as the scores were normalized on the *full* sample the " expected " figure for each occupational group would of course be 50%, as shown in brackets in the table. So far as the physician's " category 3" cases are concerned, the same general trend can be seen if one combines Groups I, II, and III (overcoming the difficulty of unstable percentages) to obtain a total figure of 7 in 102 (7%) compared with the 12 in 75 (16%) of Group IV.

Discussion

In spite of the varied responses required by these five tests, only one factor was required to account for all the common variance. This agrees with earlier work already referred to, and extends it to a new class of subjects tested under very different conditions. The present findings are also in agreement with those obtained by one of the authors (Heron, 1952) with another group of industrial workers, using a larger and more heterogeneous battery of tests which included four of those used in the present study. It should be noted, however, that when included in a larger battery, some of the present tests also provide loadings on a second factor which is uncorrelated with the first. While presenting inconsistencies which prevented confident identification, this second (bi-polar) factor was suggestive of what may be called " tendencies to hysteria or to dysthymia ", a similar finding to that reported by Eysenck (1947, 1952). The implication of this factorial impurity is, for practical purposes, that individual response to the demands of the tests in question may be of mixed origins. This stresses the importance of further work along these lines to develop " pure " tests in each of the dimensions which have been identified.

The significant correlation with the physician's ratings, while not large, is both interesting and encouraging. It is probably an underestimate due to coarse grouping of the variables and the imperfections of the factor score, but no one would have expressed surprise had there been no evidence of association at all. It would appear that a wide clinical experience with industrial workers can provide some basis for arriving at opinions regarding their mental health which are consonant with the results obtained by objective tests, though the latter may classify cases as relatively unstable which would succeed in obtaining a clean bill from the physician.

The absence of observed relationships between emotional instability scores and rheumatic symptoms or diagnosis was not surprising. It was, however, the kind of evidence required one way or the other in such an enquiry, especially in connexion with the subjective complaints of rheumatic pain. This result is consistent with the finding of the physician's that objective evidence of disc degeneration was found in many subjects who had made no complaint, while very few who had complained of symptoms were found to be free of degenerative signs on *x*-ray examination.

For the interesting finding that underground workers in this sample are less emotionally stable than sedentary surface workers, with occupationally intermediate groups in correspondingly intermediate positions on the stability continuum, no wholly satisfactory explanation occurs to the writers. It is possible to suggest that underground work constitutes a sufficient stress to affect the stability of those who in less stressful circumstances would have remained relatively unaffected. Alternatively, underground work may attract men whose personalities differ systematically from those living in the same district who chose surface employment. In favour of the first hypothesis, it is worth noting that the miscellaneous group who spend part of their working lives above and part below ground are adjacent to the underground workers on the stability continuum.

Those familiar with the views of Halliday (1943; 1948, p. 255 ff.) concerning the psychosomatic and psychoneurotic characteristics of underground miners will have seen that the present finding supports some of his contentions. It is unfortunate that he does not present data on healthy workers ; but in comparing 200 miners with 200 non-miners (all under 45) in medical referee interviews to assess " capacity for work " in men receiving sickness benefit, he attributed disablement to psychosomatic and psychoneurotic affections in 64% of miners and only 38% of non-miners. He also observed (Halliday, 1943) that " an unusual prevalence of anxiety-hysteria and pure hysteria was also noted in other ' dangerous occupations ' such as in workers at heights (typically steeple-jacks, steel erectors, slaters, window-cleaners) as well as in

workers at explosive factories." In the present investigation, no evidence was found to extend Halliday's emphasis on " hysteria simulating rheumatism ".

Conclusions

A small battery of objective tests, taking about 30 minutes to administer, has been found useful as a measure of emotional instability in a group of industrial workers. By its use further evidence has been obtained concerning the greater prevalence of psychoneurotic handicap among underground workers.

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AN INVESTIGATION INTO THE REMOVAL OF RADIOACTIVE CONTAMINATION FROM THE HANDS*

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The investigation was designed to determine the comparative value of certain washing agents in removing radioactive contamination from workers' hands, and was carried out at a production factory processing radioactive materials.

Where radioactive materials are handled cleanliness of the hands is of vital importance for the protection of the employee and for the manufacture of a product of extreme purity.

At this factory those working in contact with radioactive materials are provided with a complete change of clothing to be worn at all times in the factory and have to undergo a precise and definite washing procedure. When they actually enter an area where radioactive substances are encountered extra protective garments are provided. These consist of an overall of a boiler-suit type, a cap, rubber " surgeon's " boots, and plastic gloves. On leaving the area the gloves are washed and removed, after which the hands are scrubbed thoroughly with soap and water. The overall, cap, and boots are then removed and, before finally leaving the change-room attached to the area, the hand washing is repeated, using a proprietary cleanser (cleanser A in the investigation).

On completing the day's work and before donning their own clothing, employees remove the special factory clothing and pass through a shower-bath. Their hands are checked on machines to determine their degree of radioactive contamination. This has come to be known as " hand-monitoring ".

If hand-monitoring, which is carried out on an " alpha " hand-counting instrument (Type 1024), shows any contamination above a certain maximum permissible level the hands are washed again until the contamination has been removed.

The provision of plastic gloves does not necessarily prevent contamination. Certain jobs must be done without gloves, especially where fine or delicate manual operations are involved, such as may occur with instrument, laboratory, or clerical work ; gloves may be discarded without permission or may have puncture holes or tears developed since the last inspection and test ; the inside of gloves may be contaminated after working with bare hands ; or the hands may be contaminated by clothing after the gloves are removed.

Any radioactive contamination remaining on the hands is important for two reasons. There will be the local effect of radiation and the risk of conveying radioactive material to the mouth during eating, or, in some employees, from nail-biting.

Certain maximum permissible levels of hand contamination have been formulated, including that for alpha activity on the hands of 600 counts per minute per hand on the alpha hand-counting instrument.

For 10 months preceding October, 1950, a large number of hand-monitoring checks were carried out on employees at this factory, and 1·48% of the process workers showed some detectable radioactive contamination. The contamination was greater than 600 counts per minute per hand in only 0·22%.

Although this would appear to be reasonably satisfactory, there is no guarantee that it can be maintained without very close surveillance. The obvious aim, therefore, should be to attain 100% freedom from contamination of the hands before workers leave the factory.

The reasons why a few employees did not decontaminate their hands completely are either that the methods themselves are inadequate, or that employees do not use them in the correct manner.

At the same time, there remains some uncertainty

* Shortened version of B.M.A. Occupational Health Prize Essay, 1951.

that the best washing agents are being used. It was for this reason that this investigation was made.

A review of the literature shows that although there have been several studies of hand cleansing (Cruickshank, 1948; Forgie, 1946; Lane, 1949) it is only in the U.S.A. that tests on the removal of radioactive contaminants from the skin have been carried out (Mayer and Britton, 1948). These tests, however, were done with special isotonic solutions, incorporating detergents and germicides, on the shaven skin of rats and on dead human skin and are, therefore, not comparable with this series of tests with proprietary and other accepted washing agents on the human hand.

Further enquiries showed that no experiments on hand cleansing had been done in other similar factories but many suggestions as to the agents most suitable for removing radioactive contamination were received, and these substances were included in the tests.

The radioactive substances on the hands at the factory concerned may consist of one or more compounds. They may be bound down with grease or oil, or be physically trapped in coarse skin or under the nails. Removal, therefore, may prove difficult and the use of solvents or abrasives may result in dermatitis. Hence, a suitable washing agent, besides being efficient in removing contaminating materials, should also be safe and cause no complications after fairly frequent use. It should be pleasant to use and free from any objectionable characteristics, easily available, and not too costly.

Experimental Methods

In devising suitable experiments for comparing the efficiency of different washing agents, a contaminant comparable to the compounds likely to be met with in the factory and of known radioactivity was necessary. This contaminant could then be applied to the hands of volunteers and be removed by successive washes,* the radioactivity remaining being measured after each wash by means of the alpha hand-monitoring machine.

The Alpha Hand-Monitoring Machine.—The alpha hand-monitoring machine used (Type 1024) is an air proportional type counter. It records the count of alpha-particles from each individual hand in terms of "tolerance" (T). ("Tolerance" is a maximum permissible count of 600 alpha counts per minute per hand.)

* None of the men reported any skin trouble from these repeated washes, though two had some dryness and roughness of the hands, one after using titanium dioxide and the other following the washes with cleanser "E".

The machines to be used are switched on some time before to warm up. When a reading is required "background" is first checked by means of a special switch. Having taken the background readings on the left and right hand sides, the hands are inserted and pressure by the finger tips activates the counters. The results are recorded only after a 15-second counting period as shown on a timing dial on the machine.

The true counts are taken as the recorded hand-count minus background for each hand.

In the following experiments all the results were first recorded in terms of tolerance and then converted to counts per minute for the purpose of tabulation and analysis.

The machines were periodically checked, frequently, though spasmodically, by an artificial hand bearing a contamination of 1 × T during the whole of the series of tests.

As the machine readings from 0 to several times tolerance are marked off on an approximately logarithmic scale, readings up to 1 × tolerance (600 counts per minute) can be read off accurately to the nearest 0·1 × T (60 counts per minute), but above unity the scale becomes progressively smaller, until it is impossible to read it above 3 × T (1,800 counts per minute). Therefore, any hand counts of over 3 × tolerance were discarded. In addition, where a check hand count before contamination showed a count of more than tolerance on either hand, the man concerned was not used for that day's test.

Two machines were used to record the count remaining after each wash on each pair of hands, and, as the men were divided into two groups, a total of four machines was used throughout the tests. It was thus possible to compare each pair of machines for both left and right hands, and so obtain some evidence as to the accuracy of the machines.

From these results it was deduced that, for comparison of the results from the different washing tests, the average of the two readings obtained on either hand could be assumed to be an accurate count of the degree of contamination within the range 0–600 counts per minute.

The Experimental Subjects.—The men chosen for the experiments, all of whom were volunteers, were drawn from the chemical laboratories attached to the factory. There would be only a small order of difference between the hands of scientific staff and process workers as both have to wash their hands frequently and to wear gloves.

Thirty persons were considered necessary for each

of the tests carried out, but owing to leave and unrelated illness occasional substitution had to be made. A total of 47 men actually took part in the experiments and of these 28 were fairly regular attenders.

Nineteen tests were undertaken, only one test being carried out each day. Of the possible total of 570 there were actually 523 attendances (91·8%), giving an average of 27·5 attendances per test, but of these 20 had to be discounted for reasons already mentioned, and in all 503 attendances (88·2%) were analysed.

Six persons were tested at a time in two groups of three. This involved the use of two controllers, each with one pair of alpha hand-counting machines. Throughout the tests the controllers continually checked their methods to see that they were the same.

As the accuracy of the machines was unknown when the experiments were planned, it was considered desirable that the same men, so far as was possible, should come under the same controller using the same machines for each test. Then if machine errors or differences among the subjects were observed between the two sides the tests of each group could be compared separately. No selection as to this separation of the men into the two groups was made, however, and on the first day the first three men to arrive were sent to one side and the second three to the other side, and so on until all were divided. They were then asked to remain on the same side through the tests.

The following table shows how the men compared on the two sides :—

TABLE A
COMPARISON OF SUBJECTS ATTENDING IN THE TWO GROUPS

Personnel Factor under Comparison	Controller A (using Machines I and II)	Controller B (using Machines III and IV)
Number of regular attenders ..	14	14
Total attendance of " regulars "	220	214
Number of " reserves " ..	11	8
Total attendance of reserves ..	49	40

On all but 17 occasions out of the total of 523 attendances (3·25%) the men attended under the same controller at each visit.

The hands of all the men were measured and examined, and marked individual differences such as might introduce a difference between the groups were not found.

It was concluded that using these two groups as shown throughout the tests on their own sides, under the same controllers, and using the same pairs of machines, the results obtained from the different tests would be comparative in so far as any variable due to the subjects themselves was concerned.

Furthermore, in view of this conclusion and that relating to the accuracy of the machines, it was considered that the results from the two groups need not be analysed separately, but could be summated for each test and the mean count after each wash could be derived from the total personnel each day.

The Contaminants.—The radioactive substances chosen were radium residues and uranium peroxide (UO_4) and the bases used to hold these were vaseline (Paraff. Moll. Flav. B.P.) and talc (Cret. Gall. B.P.).

It was considered that any washing agent removing radioactive contamination in vaseline would also remove contamination mixed with industrial oil and grease, and that talc, with the addition of a little water and liquid paraffin for binding purposes, would prove similar to forms of industrial dirt as regards its holding power for any contamination.

After trials to determine the amounts required to give an approximate count of 10 × T, when rubbed onto both hands, the following contaminants were made up :—

Radium Residues in Vaseline.—The first was 0·032 g. of the sample of radium residues in 0·78 g. vaseline. This was equal to 1 ml. by volume and was delivered onto the hands from a glass syringe, to give an approximate count of 10 × T. This standard quantity was used to test the washing capabilities of all the washing agents chosen.

Uranium Peroxide (UO_4) in *Talc.*—The second was made up 2 g. of UO_4 in 1·9 g. of talc made up into a paste with 3 ml. water and 1 ml. liquid paraffin. This was equal to a level teaspoonful, from which it was delivered onto the hands to give an approximate count of 10 × T. It was used to test four selected washing agents.

Radium Residues in Talc.—The third was of 0·32 g. of the sample of radium residues in 3·57 g. talc made up into a paste with 3 ml. water and 1 ml. liquid paraffin. This was delivered onto the hands from a teaspoon to give an approximate count of 100 × T, and was used to test more rigorously the same four selected washing agents as above.

When applied, the contaminant was rubbed onto the hands for 60 seconds, the subjects being told to work it well into the skin, on the webs, and round the nails.

The Washing Agents.—The washing agents were chosen for a variety of reasons, some on the recommendation of outside authorities. The 11 chosen were as follows :—

(1) White Windsor soap (called " hard soap " in this report to distinguish it from liquid soap), as already used in this factory ; (2) liquid soap ; (3) cleanser A, a proprietary gel, as already in use at this factory and widely in industry, consisting of soap dissolved in petroleum ether with the addition of a small quantity of liquid germicide ; (4) " woodflour," a proprietary mixture of 50% soap powder and 50% woodflour, which Cruickshank (1948) considered to be most valuable in removing industrial mineral oil from workers' hands ; (5) cleanser B, a proprietary gel including sulphonated castor oil with other adjuvants ; (6) " neutral sulphonated castor oil ", consisting of 98% of N.S.C.O. with 2% wetting agent, the mixture being diluted to 1 part in 5 of distilled water. This washing agent is recommended as an industrial hand cleanser in the oil dermatitis placards of the Ministry of Labour and National Service (Factory Department) ; (7) titanium dioxide, recommended by the United States Atomic Energy Commission (U.S.A.E.C.) and National Research Council, Canada (N.R.C. Canada) for the removal of radioactive contamination ; (8) cleanser C, a proprietary cleansing paste recommended by the National Physical Laboratory, a slightly abrasive (siliceous) orthodox hand cleanser in a water base ; (9) cleanser D, a proprietary liquid detergent, also used by Cruickshank (1948) in his experiments, consisting of a solution of wetting agent and germicide in medicinal liquid paraffin ; (10) cleanser E, a sulphated secondary alcohol of the type R–CH ($O–SO_3Na$)–R′ (where R and R′ range from C7 upwards) referred to by Forgie (1946) in an article on skin cleansing, and well known as an industrial wetting agent ; (11) sodium citrate and potassium permanganate, also recommended by U.S.A.E.C. and N.R.C. Canada, for removal of Beta-gamma contamination.

The quantities of these 11 substances used in the experiments were the same in each case, so far as it was practicable to control this factor. The standard amount used was that which would be used by the average person if washing with that particular substance, as assessed by trial and error in the actual use of the material. Limitations as to the amount which could be used were obvious in some cases ; for example, the quantity of a liquid agent which could be held in the hands without being spilled. Furthermore, the same amount of all similar cleansers was used : 4 ml. of the liquids were delivered onto the hands in two lots of 2 ml. each, the first delivery being gently rubbed in before the second one was given ; powders were levelled off in small containers (approximately 5 ml. by volume) for dispensing ; and a level teaspoonful of the gels (approximately 6 ml.) was used.

Hard soap was the only difficult one to assess in this way, and a fixed time for lathering-up a damp scrubbing brush on a sizeable piece of soap was estimated.

All the agents were used in the manner recommended by the manufacturers or by other authorities and users.

In all cases tests were made to establish that the quantities delivered were consistent.

Timing.—It was estimated that half a minute per hand was a customary and suitable period for attention to each hand in normal washing. Accordingly, a fixed time-table was drawn up and the same methods and timings used for every wash.

Example : *Cleanser B.*—A given quantity of the cleansing agent was put on the dry hands of the person under test by the test controller, and this was worked well into the hands for 30 seconds.

The scrubbing brush was taken in the right hand and the bristles dipped into the water in the wash-basin, which had been filled by the controller, then the left hand was scrubbed : palm, back, side, and thumb for 10 seconds, nails for 10 seconds, webs and sides of fingers for six seconds, junction of wrist and hands for four seconds. (The lapse of seconds and the parts to be scrubbed were called out by the controller.)

The brush was then taken into the left hand and again dipped into the water, and the scrubbing repeated on the right hand. The hands were next rinsed thoroughly in the basin of water for 15 seconds. Finally, the hands were dried on a clean towel.

Cross Contamination.—It was arranged that the persons under test used the same individual wash-basin, scrubbing brush, and towel for each of their four washes.

Scrubbing brushes and towels were replaced with new and clean ones respectively for each person and for each test.

While the hands were being checked on the machines between washes the controller cleaned out and refilled the three wash-basins in use.

It was considered that these arrangements would eliminate any risk of cross-contamination between the subjects.

Any small degree of re-contamination of an individual's hands that might occur from the scrubbing brush and towel was not likely to be of any significance, and in any case would probably be no more than that likely to occur in the factory change-rooms.

During analysis of the results it was found that there were only 11 occasions (2·1%) when re-contamination might have occurred, as shown by a small increase in hand count after a third or fourth wash.

Water Temperature.—No standard temperature was laid down for the water in the wash-basins, but each controller endeavoured to ensure much the same degree and quantity of pleasantly hot water each time he filled the basins.

Consistency of the Routine.—In order to test the efficiency of the routine, Test No. 11 was a repetition of Test No. 1, using hard soap.

Except in the results after the first washes where the counts came outside the accepted accurate range of the machines, there was no significant difference between the counts recorded after the four washes with hard soap in these two tests (Table 1).

TABLE 1

ANALYSIS OF HAND WASHES BY THE COUNT REMAINING AFTER EACH WASH

Test No.	Washing Agent	No. of Hands Tested	Mean Readings per Hand after Successive Washes (in counts/minute)			
			Wash 1	Wash 2	Wash 3	Wash 4
	Contaminant: Radium residues in vaseline (approximately 6,000 cts./min./hand)					
1	Hard soap	60	*++317·8	126·8	64·8	28·1
2	Cleanser D	60	++596·8	203·3	113·8	73·0
3	Woodflour	54	++687·5	214·4	125·9	88·9
4	Cleanser B	54	++500·0	172·8	110·0	73·0
5	Liquid soap	54	++680·0	191·3	113·6	57·0
6	Titanium dioxide	48	†Totally unreliable	++683·2	++404·9	272·5
7	Neutral sulphonated castor oil	56	Totally unreliable	++651·5	++373·7	271·3
8	Cleanser C	48	++784·2	281·3	175·9	97·2
9	Cleanser E	52	++957·1	++362·9	229·1	147·7
10	Cleanser A	52	++620·2	195·8	118·9	62·9
11	Hard soap	54	++611·7	169·6	78·9	33·1
1 and 11	Hard soap	114	++457·0	147·1	71·4	30·4

†Totally unreliable signifies that many of these results were so high as to give unreliable readings on the machine scale. *Numbers marked ++ include counts of 600 or more, and are, therefore, less reliable than the other results given.

This suggests that the routine of the tests was consistent.

Procedure

The men attended each morning for the tests. A different washing agent and/or contaminant was used each day.

The men attended in groups of six, spaced out evenly throughout the morning, and three men came under the supervision of each controller.

Each day's test was carried out in the following order :—(*a*) Hands checked in turn on two alpha hand-monitoring machines and results entered up on a special card used for all counts ; (*b*) contamination ; (*c*) first wash ; (*d*) hands rechecked on the same two machines and results noted ; (*e*) washings, followed by countings, repeated three times, or until both hands showed a reading of zero, i.e., instrument background count only.

Following the use of the first 10 washing agents against the radium residues in vaseline contaminant, hard soap was used again as a check.

Then the selected four agents were used on the UO_4 and radium residues in talc contaminants.

Finally, a special test with nine men was undertaken with the eleventh agent (sodium citrate and potassium permanganate) against radium residues in vaseline as the contaminant. This method was considered industrially impracticable because of the quantities required, and the time taken for use. It could not be introduced in a comparable manner amongst the other tests. (A special Appendix on this test is added at the end of this paper.)

Experimental Results and Discussion

The washing agents used in the tests were compared in two ways : (1) According to the count remaining after each wash ; (2) by the number of hands cleared of contamination by each wash.

Results Analysed by the Count Remaining after Each Wash.—The results obtained in the washing tests were summated for each combination of contaminant and washing agent, and the mean count

TABLE B

RESULTS WITH RADIUM RESIDUES IN VASELINE AS CONTAMINANT

Washing Agent	Hard Soap	Liquid Soap	Cleanser A	Cleanser B	Cleanser D	Wood-flour	Cleanser C	Cleanser E	N.S.C.O.	Titanium Dioxide
Hand count after Wash 4	30·4	57·0	62·9	73·0	73·0	88·9	97·2	147·7	271·3	272·5

TABLE 2

COMPARISON OF WASHING AGENTS BY PERCENTAGE OF RADIOACTIVE MATERIAL REMOVED BY WASHES

Test No.	Washing Agent	No. of Hands Tested	Percentage of Original Count Removed by First Two Washes	Percentage of Count Remaining Removed by Wash 3	Percentage of Count Remaining Removed by Wash 4	Percentage of Original Count Removed by All Four Washes
	Contaminant : Radium residues in vaseline (approximately 6,000 cts. /min. /hand)					
1	Hard soap	60	97·9	48·9	56·6	99·5
2	Cleanser D	60	96·1	44·0	35·9	98·8
3	Woodflour	54	96·4	41·3	29·4	98·5
4	Cleanser B	54	97·1	36·3	33·6	98·8
5	Liquid soap	54	96·8	40·6	49·6	99·1
6	Tita[illegible]oxide	48	—	—	—	95·5
7	Ne[illegible]phonated castor oil	56	—	—	—	95·5
8	Cleanser C	48	95·3	37·5	44·7	98·3
9	Cleanser E	52	—	—	35·7	97·5
10	Cleanser A	52	96·7	39·3	47·1	99·0
11	Hard soap	54	97·2	53·5	58·0	99·4
1 and 11	Hard soap	114	97·6	51·5	57·4	99·5

(per hand) remaining after each wash was calculated.

Table 1 shows these results in full for the first 11 washing tests. The summary Table B shows the results after the fourth wash only, an average of the two tests with hard soap being given.

Table 1 also demonstrates the quick dramatic reduction in count with the first wash. This is presumably due mainly to the physical agencies of scrubbing and water. These common factors in all the first washes are apparent to a much smaller degree in successive washes, when the properties of the washing agent become the main factor in removing the contamination. Thus it is in the second, third, and fourth washes that the truly comparative values of the washing agents are to be assessed.

Further examination of Table 1 appears to indicate that, where the counts are within the assumed accurate range of the machines, successive washings produce an exponential fall in the counting rate as one would expect. Hence the efficiency of a cleanser can be expressed by the percentage of radioactive material removed by a standard wash, and this is shown in Table 2.

From this it would then appear that the washing agents can be grouped into three categories according to their efficiency :—

Group (1)	High efficiency ..	Hard soap
Group (2)	Medium efficiency	Liquid soap Cleanser B Cleanser A Cleanser D Woodflour Cleanser C
Group (3)	Poor efficiency ..	Cleanser E Neutral sulphonated castor oil Titanium dioxide

Further analysis by calculation of the standard deviation of the means, and using these figures to compare the significance of the results shown in Table 1, confirms this grouping. Each group is statistically significantly better than the next in order of efficiency.

From these results, the following were selected for the remaining tests :—Hard soap, apparently the best washing agent ; cleanser B, a gel in the group of second-best agents ; woodflour, also in the group of second-best agents, and a powder found to be the best washing agent in Cruickshank's (1948) work on the removal of mineral oils from the skin ;

TABLE 3

ANALYSIS OF HAND WASHES BY THE COUNT REMAINING AFTER EACH WASH

Test No.	Washing Agent	No. of Hands Tested	Mean Readings per Hand after Successive Washes (in cts./min.)			
			Wash 1	Wash 2	Wash 3	Wash 4
	Contaminant : Radium residues in talc, giving contamination of approximately 60,000 cts. min. hand					
12	Cleanser E	50	†Totally unreliable	*++1,154·7	++634·8	451·2
13	Hard soap	54	Totally unreliable	++1,034·9	++585·0	398·4
14	Cleanser B	50	Totally unreliable	++752·4	++479·4	339·0
15	Woodflour	58	Totally unreliable	++633·1	354·9	238·5
	Contaminant : UO_3 in talc giving contamination of approximately 6,000 cts. min./hand					
16	Cleanser E	58	++566·9	192·6	85·6	39·0
17	Hard soap	48	337·6	88·2	53·8	21·9
18	Cleanser B	48	++827·5	220·0	110·0	51·9
19	Woodflour	48	316·6	67·5	25·6	5·0

†Totally unreliable signifies that many of these results were so high as to give unreliable readings on the machine scale. *Numbers marked ++ include counts of 600 or more, and are, therefore, less reliable than the other results given.

TABLE C

MEAN COUNT PER HAND (IN COUNTS PER MINUTE) REMAINING AFTER WASH 4

Contaminant	Radium Residues in Talc				UO_4 in Talc			
Washing Agent	Woodflour	Cleanser B	Hard Soap	Cleanser E	Woodflour	Hard Soap	Cleanser E	Cleanser B
Hand count after Wash 4 . .	238·5	339·0	398·4	451·2	5·0	21·9	39·0	51·9

cleanser E, a liquid cleanser, not in the best groups, and largely tested as a control agent.

Table 3 shows the results obtained using these agents against two contaminants, UO_4 in talc and radium residues in talc. Although the large contaminating dose of the latter made it not possible to obtain reliable figures for all but a few of the washes, the results are still of value.

Table C, a summary of Table 3, shows these results after the fourth wash only.

Table 4 shows the percentage of radioactive material removed by a standard wash against these two contaminants and the washing agents can again be grouped by their efficiency, the grouping being confirmed by the statistical significance.

Most of the results fall outside the assumed accurate range of the machines, but they suggest :—

Radium Residues in Talc

Group (1)	High efficiency	Woodflour
Group (2)	Less efficient	Cleanser B
		Hard soap
		Cleanser E

The results for UO_4 in talc gave a somewhat different picture.

UO_4 in Talc

Group (1)	High efficiency	Woodflour
Group (2)	Lower efficiency	Hard soap
Group (3)	Least efficient	Cleanser E
		Cleanser B

Results Analysed by Number of Hands Cleared after Each Wash.—Table 5 shows the number of hands "cleared" after each wash, clearance being accepted when the true count on the hand was nil.

Again the results show a possible method of grouping the washing agents by their efficiency.

Other factors to be taken into account in assessing these cleansing agents are the possible harm to the user ; simplicity as regards use and dispensing ; economy ; and psychology, based on its ability to lather well and its attractiveness. Hard soap, liquid soap, and woodflour would appear to show up well under such an assessment.

TABLE 5

PERCENTAGE NUMBER OF HANDS CLEARED* AFTER THE VARIOUS WASHES

Washing Agent	No. of Hands Tested	Percentage No. of Hands Cleared after Successive Washes			
		Wash 1	Wash 2	Wash 3	Wash 4
Contaminant : Radium residues in vaseline (approximately 6,000 cts./min./hand)					
Hard soap	114	0·9	6·1	26·3	56·1
Cleanser D	60	—	—	6·7	20·0
Woodflour	54	—	1·9	5·6	16·7
Cleanser B	54	—	—	7·4	25·9
Liquid soap	54	—	—	13·0	44·4
Titanium dioxide	48	—	—	—	2·1
Neutral sulphonated castor oil	56	—	—	—	1·8
Cleanser C	48	—	—	—	4·2
Cleanser E	52	—	—	—	7·7
Cleanser A	52	—	—	3·8	19·2
Contaminant : Radium residues in talc (approximately 60,000 cts./min./hand)					
Cleanser E	50	—	—	—	—
Hard soap	54	—	—	—	—
Cleanser B	50	—	—	—	4·0
Woodflour	58	—	—	—	3·4
Contaminant : UO_4 in talc (approximately 6,000 cts./min./hand					
Cleanser E	48	—	4·2	10·4	37·5
Hard soap	48	—	12·5	45·8	68·8
Cleanser B	48	—	—	8·3	29·2
Woodflour	48	—	10·4	60·4	91·7

* Clearance was accepted when the true count on the hand was nil (i.e. the recorded hand count was the same as the machine background).

TABLE 4

COMPARISON OF WASHING AGENTS BY PERCENTAGE OF RADIOACTIVE MATERIAL REMOVED BY WASHES

Test No.	Washing Agent	No. of Hands Tested	Percentage of Original Count Removed by First Two Washes	Percentage of Count Remaining Removed by Wash 3	Percentage of Count Remaining Removed by Wash 4	Percentage of Original Count Removed by All Four Washes
	Contaminant : Radium residues in talc giving contamination of approximately 60,000 cts./min./hand					
12	Cleanser E	50	—	—	—	99·2
13	Hard soap	54	—	—	—	99·3
14	Cleanser B	50	—	—	—	99·4
15	Woodflour	58	—	—	32·8	99·6
	Contaminant : UO_4 in talc giving contamination of approximately 6,000 cts./min./hand					
16	Cleanser E	58	96·8	55·6	54·4	99·4
17	Hard soap	48	98·5	39·0	59·3	99·6
18	Cleanser B	48	96·3	50·0	52·8	99·1
19	Woodflour	48	98·9	62·1	80·5	99·9

TABLE D

GROUPING OF WASHING AGENTS BY PERCENTAGE OF HANDS CLEARED AFTER FOURTH WASH

Group	Washing Agent	Percentage of Hands Cleared after Wash 4
	Contaminant : Radium residues in vaseline	
(1)	Hard soap	56
(2)	Liquid soap	44
(3)	Cleanser B	26
	Cleanser D	20
	Cleanser A	19
	Woodflour	17
(4)	Cleanser E	8
	Cleanser C	4
	Titanium dioxide	2
	Neutral sulphonated castor oil	2
	Contaminant : UO_4 in Talc	
(1)	Woodflour	92
(2)	Hard soap	69
(3)	Cleanser E	37
	Cleanser B	29

An insufficient number of hands was cleared in the tests using radium residues in talc as the contaminant for the results to be of value.

Conclusions

Under the reported conditions of test, hard (white Windsor) soap was the most effective agent for cleansing the hands from contamination with radium residues in a greasy base. Other agents of some value were liquid soap, cleanser B, cleanser A, cleanser D, and woodflour.

Woodflour was the most effective of the four agents tested in removing dry contaminants made up in talc (with minimal oil- and water-binding substances).

Sodium citrate and potassium permanganate, although apparently of value as combined washing agents, were considered to be industrially impracticable except in special cases, but are worthy of further investigation in practice for special washes of hands showing persistent contamination.

Cruickshank (1948) has shown that woodflour is a valuable agent for removing mineral oil from the skin. In view of this, hard soap and woodflour would appear to be the two most effective washing agents for the factory change-rooms.

These tests were used with radium and uranium contamination. Different elements and compounds are likely to behave in different ways and so respond in different manners to the various washing agents.

It cannot be assumed that the results obtained in these experiments will apply equally to other radioactive elements, and the fission elements may respond quite differently.

Summary

A method is described of assessing the comparative value of certain washing agents in removing radioactive contamination from workers' hands. The method is based on the use of alpha hand-monitoring machines to detect contamination before and after a number of washes.

Ten cleansing agents were compared, and of these white Windsor soap and a mixture of equal parts of soap-powder and woodflour were found to be the two most effective for cleansing the hands of contamination with substances containing uranium and radium.

I desire to thank Sir Christopher Hinton, Deputy Controller of Production (A.E.), and the Chief Medical Officer, Ministry of Supply, for permission to publish this paper ; also the Principal Medical Officer, Division of Atomic Energy (Production), and my colleagues at the factory for their advice and encouragement, the principals and staff of the Chemical Inspectorate and Safety Department at the Factory for their assistance, and the manufacturers of the various cleansing agents for the supply of samples.

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APPENDIX A

The Sodium Citrate-Potassium Permanganate Washing Agent

This washing agent could not be introduced amongst the other agents used on a comparative basis because of the large quantities of materials used, the long time required, and the difficulty in giving comparative timings for scrubbing, rinsing, etc.

A special test using nine persons was, therefore, made to give some assessment of the value of this washing method.

The contaminant used was radium residues in vaseline to give a contamination of approximately 6,000 counts per minute.

The washing method consisted of immersing the hands in a basin of 24% sodium citrate solution for two minutes, then rubbing a saturated solution of potassium permanganate into the hands for one minute. With the scrubbing brush moistened in sodium bisulphate solution, each hand was scrubbed in turn until all the permanganate stain was removed. Finally, the hands were rinsed and dried.

The results obtained are shown in the following table :—

Wash No.	Mean Readings per Hand	No. of Hands Cleared (No. used = 18)	Percentage of Hands Cleared
1	920	—	—
2	111·7	1	5·6
3	41·7	5	33·3
4	5·0	16	88·8

This would appear to show that the method is of value, but its assessment by the factors used for the other agents immediately indicates how impracticable it would be as a method of washing in the change-rooms.

Assessed by the properties of simplicity, economy, and psychology, this washing agent compared unfavourably with the other agents used in the tests. In addition, large quantities of materials and containers are required, and detailed supervision would be necessary.

However, it might be of value as an additional washing method in resistant cases, but again, time is a limiting factor at the end of a worker's shift, and the above results do not indicate its true worth compared with the other tests.

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A FIELD STUDY OF OCCUPATIONAL DEAFNESS*

BY

COLIN M. JOHNSTON

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Fosbroke (1830–31) described deafness in blacksmiths since when there have been many investigations of deafness caused by noise in industry. But there are still many questions of practical importance to the industrial medical officer as yet unanswered. He needs to know how loud a noise must be to cause deafnesss, how to measure noise, and the methods of protecting the workman's hearing where the noise is very loud. These questions cannot be answered simply as there are many factors to be considered, the more important of which are the duration of exposure to noise, its loudness when it reaches the ear, and the susceptibility of the ear to damage (Perlman, 1945).

If a group of men have worked in a loud but steady noise for the same number of years the effects on the hearing of the men will vary widely. Thus it is not possible to give a precise level of noise above which hearing will be impaired. Bunch (1942) and MacLaren and Chaney (1947) agree that noise of an average overall value of 70 db† above a standard reference intensity of 0·0002 dyne/sq. cm. is innocuous and that a noise of 100 db or more greatly increases the incidence of impaired hearing.

The assessment of the hearing loss produced by acoustic trauma requires a method which will exclude deafness due to other causes. Larsen (1939), Fowler (1928), Bunch (1937), Perlman (1945), Nussdorfer (1942), Maclaren and Chaney (1947), and Weiss (1947) agree that a circumscribed loss of hearing in the high tones, 3,000–6,000 c.p.s., the so-called " C_5 dip," is to a certain extent typical of traumatic deafness. It is known, however, that this circumscribed hearing loss may be due to other causes. As Caussé and Falconnet (1947) state, it is simply the expression of a special fragility in this region of the auditory spectrum. Nevertheless it is probable that a well marked loss of hearing in the 3,000–6,000 c.p.s. frequency range with markedly smaller losses in the other regions of the auditory spectrum, particularly in the region above 6,000 c.p.s., is pathognomonic of traumatic deafness. Weiss (1947) described the development of the C_5 dip and MacLaren and Chaney (1947) classified the severity of their cases according to the development of the " dip ".

*Based on a report to the Medical Research Council's Committee on the Medical and Surgical Problems of Deafness.

†Decibel (db) is the unit of intensity of sound. In Great Britain it is usually applied to the measurement of pure tones only. For the measurement of the loudness of noise the phon may be employed. For a " noise " of a frequency of 1,000 c.p.s. (cycles per second) the decibel and phon are identical. For noise, which consists of a mixture of pure tones of different frequencies, a subjective comparison is made with a pure tone of 1,000 c.p.s. Hence the phon is not a physical unit of energy but an approximate expression of the loudness of a noise as heard by the observer. In the American literature the decibel is also used to describe the loudness of noise.

Present Investigation

The investigation was made between June, 1948, and May, 1949, in three factories in the Birmingham area (Messrs. Edwin Danks Ltd. of Oldbury, John Garrington and Sons Ltd., of Bromsgrove, and Guest Keen and Nettlefold Ltd., of Birmingham). The manufacturing processes carried out in these factories gave rise to many types of noise, intermittent or continuous, and with various proportions of low and high frequencies. The National Physical Laboratory gave their cooperation and carried out a full series of noise level measurements.

Boiler Making.—For chipping, caulking, and riveting a portable compressed air hammer in which various tools can be mounted is used. The hammers weigh from 7 to 15 lb. and they deliver up to 600 blows per minute. The light hammers give a rapid succession of light blows and are used for caulking—the operation in which the edges of a rivet or a plate are turned in to make a steam-tight joint. The medium and heavy hammers are mainly used for riveting or chipping.

When riveting, the early stages of forming the head will be relatively quiet when the hammer touches only the heat-softened rivet, but in the later stages when the edge of the tool touches the part being riveted hard metal meets hard metal and more noise is produced. On certain types of work, particularly shipbuilding, several hammers are

often in use simultaneously and the noise is conducted by metal throughout the fabric. Although the peak noise levels are no higher in shipbuilding, the workman is more continuously subjected to noise of a traumatizing intensity than his fellow in the boiler shop. Of the two methods of joining together steel sheets, welding, which necessitates the chipping of excess metal, is just as noisy as riveting. In pneumatic riveting the riveter is assisted by a " holder-up " or " backer-up " who inserts the rivet and exerts counter pressure with a heavy tool or another pneumatic hammer whilst the head is being formed. When riveting boilers the " holder-up " works inside the boiler and is therefore exposed to more noise than the riveter.

Plate Fitting.—In this work the plates and end of a boiler are assembled for riveting or welding. Minor adjustments are made to the curve of a part by hammering with a heavy sledge hammer. With certain jobs the noise levels from hard hammering may be intense, but the workman is exposed for shorter periods to more intense noise than the chipper or riveter.

Other processes include welding, template making, shearing, bending, drilling. By themselves these operations make relatively little noise but those who do this work are subjected to the noise of pneumatic tools and hard hammering, usually at a distance of several yards but occasionally in close proximity.

Drop Forge Industry.—Red hot steel ingots are forged by stamping hammers in dies. The lower half of the die rests on a firm foundation and the upper half is fixed to the lower surface of a weight of up to 2½ tons. The weight is raised to a height of two to six feet, according to the strength of blow required and allowed to drop by gravity ; with the steam hammer it is aided by steam pressure. The ingot is roughly shaped in one part of the die by several light blows and is then placed on another part of the die where harder blows are given to form the final shape. The last blow is the hardest and emits a metallic ring when the two halves of the die come in contact. There is also a continual roar produced by oil-fired furnaces used for heating the ingots and a high-pitched squeal or various clanking noises of the hammers. The work is carried out in long sheds where from seven to 15 hammers of various sizes are in continuous use. The noise, the heat of the furnaces and ingots, the continual lifting of heavy forgings, together with the dusty, smoke-laden atmosphere, make the trade, although well paid, extremely arduous. The majority of the workmen seek less strenuous employment after the age of 40.

Screw Manufacture.—In the shop studied, steel screws for wood work were being made on automatic machines. The blank for the screw is made from wire of appropriate thickness on " heading " machines. The " turning " section trims the head of the blank and cuts the " nick " or slot for the screw driver. Finally the thread or " worm " of the screw is cut on an automatic lathe. The noise in all sections is of a fairly constant intensity, being highest in the heading section and lowest in the turning section. Many of the operatives in the turning section, however, work close to the heading machines.

Method of Examination of Subjects

At two factories disused underground air raid shelters were fitted with double doors. These shelters were more than 50 yards from the nearest workshop and, apart from occasional and infrequent rumbling noises of passing traffic, ambient noise was at a low level. At another factory the workers were examined in a quiet room in the factory medical department situated 100 yards away from the nearest workshop.

All the subjects came straight from their work and after a preliminary explanation of the purpose of the investigation and the recording of their answers to a set questionnaire, underwent a short examination of the ears, nose, and throat. Cerumen, if present, was removed and the hearing was then tested by tuning fork (C512), speech, watch tick, and pure tone audiometry. For speech tests the subject sat with the ear being tested towards the observer, blocking the opposite ear by pressure on the tragus. Mixed letters and numbers were read in a soft (residual air) whisper and a conversational voice.

The following list of mixed numbers and letters were read in groups of three :

X2C	4AZ	SA5	U8G
1SN	M7D	L85	7BN
83Y	09F	3H6	X9E
LP6	3KI	V4Q	82C

The maximum distance at which two or more groups of three numbers or letters could be correctly repeated was recorded for each ear separately. Masking was employed where necessary.

Pure tone audiometry was made with a " maico D5 " audiometer by air conduction only, using a single ear piece. This latter test was started within 20 to 30 minutes of the subject leaving his place of work. The hearing was tested at frequencies of

64, 128, 256, 512, 1,024, 2,048, 2,896, 4,096, 5,792, 8,192 and 11,584 c.p.s. (The maximum calibrated output of this instrument is 100 db at all frequencies, except 128 and 11,584 c.p.s. where it is 70 db, and at 256, 5,792 and 8,192 c.p.s. where it is 80 db.)

Results of Hearing Tests

Two hundred and nineteen workers were examined, but in 28 bilateral ear disease of an infective or degenerative origin not due to acoustic trauma was found, leaving 191 for consideration.

Figs. 1 to 7 show the relation between the duration of work in the trades studied and the hearing loss of the better ear to speech at conversational level. They show that after any given period of exposure to noise the workers in each occupational group show wide variations in the degree of damage to their hearing. Although a high proportion of the workers in each of the factories visited was examined, (all the chippers, riveters, and heading machinists were examined) the numbers in each group are small and precise conclusions are not possible.

The results shown in Figs. 1 to 7 are summarized in Tables 1 and 2. From Table 1 it will be seen that the number of men with more than 20 years' exposure who were unable to hear a conversational

TABLE 1

NO. OF MEN WITH HEARING LOSS AFTER MORE THAN 20 YEARS' EXPOSURE IN DIFFERENT TRADES RELATED TO INTENSITY OF NOISE

Occupation	Noise Level (phons)	Total No. of Men	No. of Men with Hearing Loss	
			I*	II
Chippers and riveters	More than 130	12	9	11
Stampers	117–130	11	7	9
Platers	130	12	6	7
Headers	108–112	14	4	5
Welders, etc. ..	90–114	12	2	4
Wormers	105–108	13	1	1
Turners	100–101	24	0	1

*I = unable to hear conversational voice at 3 feet.
II = " " " " " " 10 "

TABLE 2

NO. OF MEN WITH HEARING LOSS AFTER LESS THAN 20 YEARS' EXPOSURE IN DIFFERENT TRADES RELATED TO INTENSITY OF NOISE

Occupation	Noise Level (phons)	Total No. of Men	No. of Men with Hearing Loss	
			I	II
Chippers and riveters	More than 130	2	0	0
Stampers	117–130	37	4	7
Platers	130	8	1	2
Headers	108–112	6	0	2
Welders, etc. ..	90–114	18	0	0
Wormers	105–108	13	0	1
Turners	100–101	9	0	0

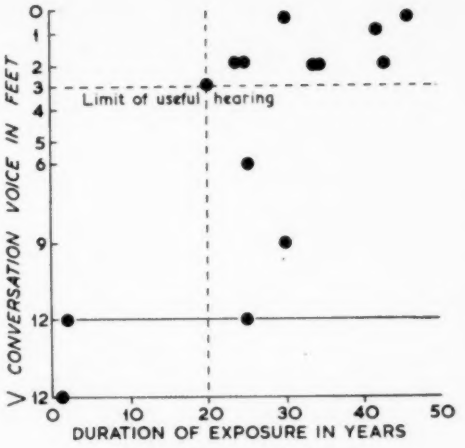

FIG. 1—Chippers and riveters.

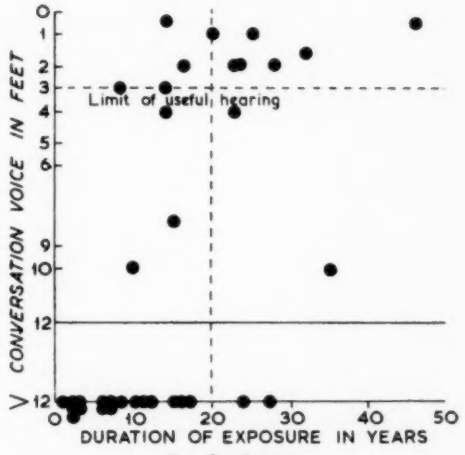

FIG. 2.—Stampers.

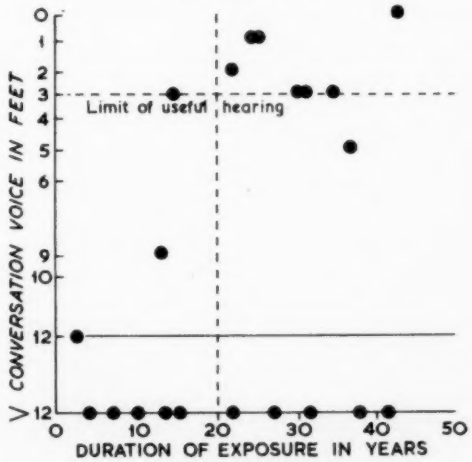

FIG. 3.—Platers.

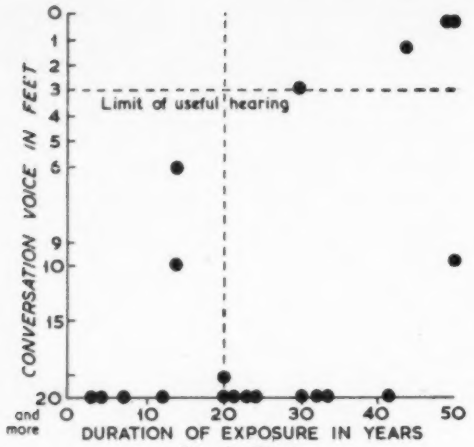

FIG. 4.—Headers.

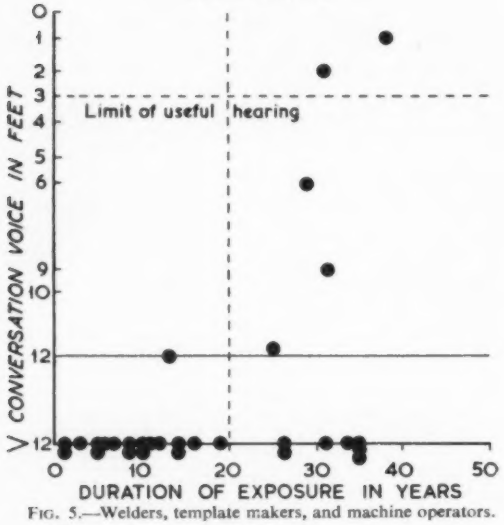

FIG. 5.—Welders, template makers, and machine operators.

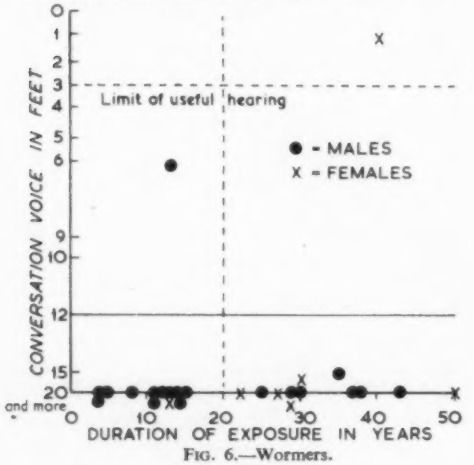

FIG. 6.—Wormers.

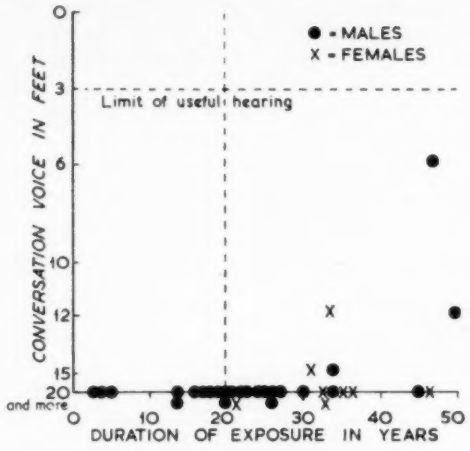

FIG. 7.—Turners.

voice at 3 feet and at 10 feet bears a definite relationship to the intensity of the noise in the trade, but Table 2 shows that the same relationship is not apparent for the men with less than 20 years' exposure.

Table 3 summarizes the audiometric results. In at least 70% the maximum loss occurred at a single

TABLE 3
FREQUENCY OF MAXIMUM LOSS OF HEARING AT VARIOUS FREQUENCIES IN 190* WORKERS

	No. of Men	Percentage of Total
2896 c.p.s.	53	28
2896 and 4096 c.p.s.	32	17
4096 c.p.s.	61	32
4096 and 5792 c.p.s.	14	8
5792 c.p.s.	18	9
2896 to 5792 c.p.s.	8	4
Complete loss above 2048 c.p.s.	4	2

*Excluding one case with a normal audiogram.

frequency. In the remainder the maximum loss was equal at two or more frequencies, e.g. a flat-bottomed "C_5 dip." The maximum loss most often occurred to tones at a frequency of 4,096 c.p.s. (34%), but a maximum loss to tones at a frequency of 2,896 c.p.s. was almost as common (28%). If, in addition, the audiograms with a "C_5 dip" at 5,792 c.p.s. and those with a flat-bottomed "C_5 dip" are considered, the mean value for the position of the dip lies at less than 4,096 c.p.s.

The development of the "C_5 dip" is demonstrated by examination of the series of audiograms of which Figs. 8 to 13 are a selection. The "C_5 dip" at first appears as a steep-sided notch of usually one or occasionally up to two octaves in

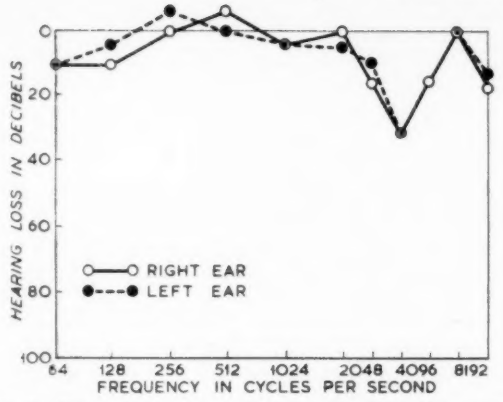

FIG. 8.—Stamper, age 29. Duration of exposure, three months. Whispered voice heard at 10 ft. distance from both ears.

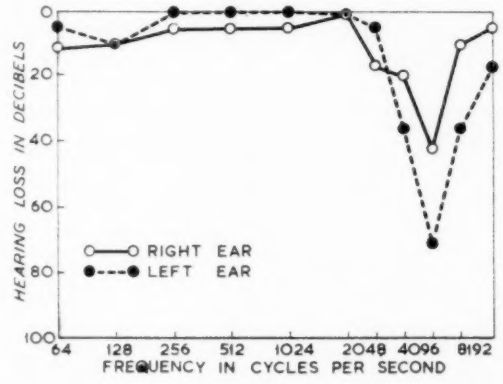

FIG. 9.—Stamper, age 22. Duration of exposure, one and a half years. Whispered voice heard at 10 ft. distance from both ears.

width (Fig. 8). With longer exposure to noise the apex of the dip descends (Fig. 9), and in most cases the sides remain steep until the hearing loss at the apex of the dip lies between 60 and 80 db (Fig. 10). Up to this stage the hearing at other frequencies is not affected except in the case of the stampers, where some loss occurs at frequencies below 2,048 c.p.s. The hearing at 8,192 c.p.s. is within normal limits for the age of the individual. At a later stage the sides of the "C_5 dip" become less steep due to losses at frequencies immediately above and below, with some additional loss at a frequency of 11,584 c.p.s. (Fig. 11). The widening of the mouth of the dip, together with a continued increase in its depth, continues (Figs. 11 and 12) until total loss of hearing to tones above a frequency of 1,024 or 2,048 c.p.s. occurs (Fig. 13). In the few audiograms obtained showing this extreme degree of deafness there was an equal loss of hearing at frequencies of 64, 128, and 256 c.p.s.

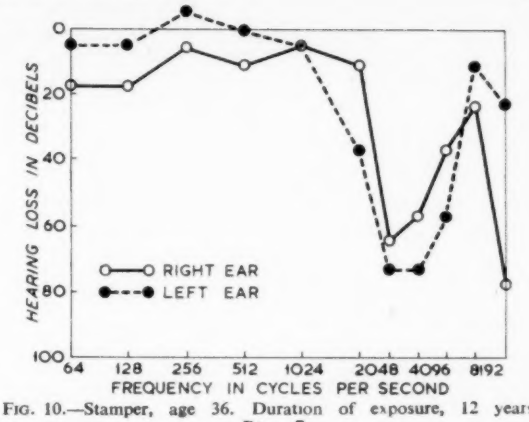

FIG. 10.—Stamper, age 36. Duration of exposure, 12 years. Whispered voice heard at $\frac{Rt}{Lt} = \frac{7}{4}$ ft. distance.

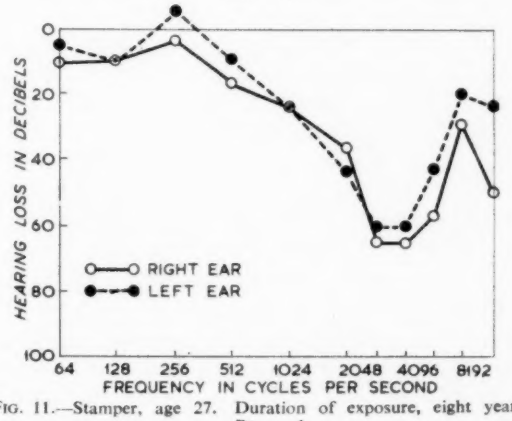

FIG. 11.—Stamper, age 27. Duration of exposure, eight years. Whispered voice heard at $\frac{Rt}{Lt} = \frac{1}{1{\cdot}5}$ ft. distance. Conversational voice heard at more than 10 ft. distance from both ears.

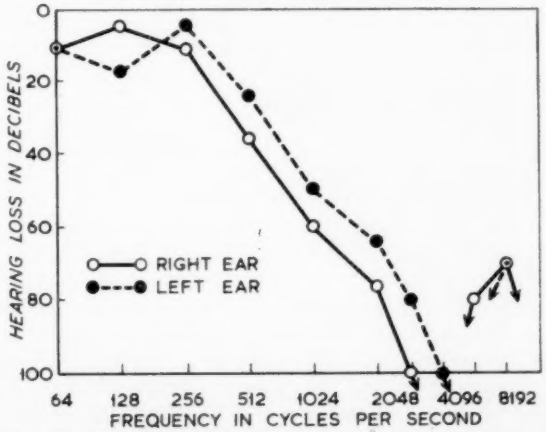

FIG. 12.—Chipper, age 60. Duration of exposure, 43 years. Whispered voice heard at $\frac{Rt}{Lt} = \frac{\text{Contact}}{0{\cdot}25}$ ft. distance. Conversational voice heard at $\frac{Rt}{Lt} = \frac{1}{2}$ ft. distance.

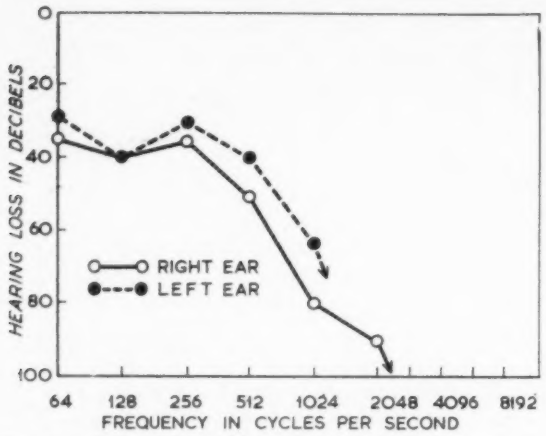

FIG. 13.—Chipper, age 60. Duration of exposure, 46 years. Whispered voice not heard. Conversational voice heard at $\frac{Rt}{Lt} = \frac{\text{Contact}}{0{\cdot}25}$ ft. distance.

Relation of External and Middle Ear Conditions to Occupational Deafness

Cerumen.—Meatal occlusion of long standing was found in one subject only. His audiogram for the right ear (Fig. 14) made after the removal of wax showed little loss of hearing, whereas the left ear in which there was no wax showed loss in the C_5 region.

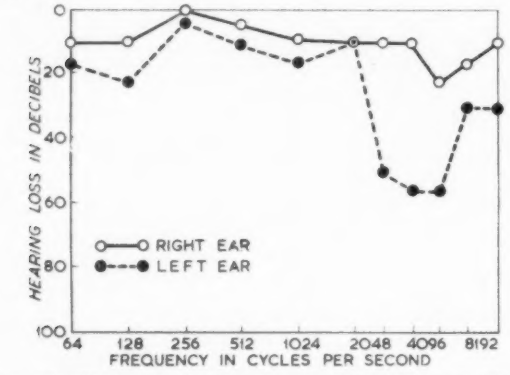

FIG. 14.—Welder, age 31. Duration of exposure, 16 years. Meatal occlusion of long standing in right ear. Audiogram made after removal of wax.

Chronic Adhesive Otitis Media.—Out of a total of 438 ears in 219 subjects, 19 ears in 17 subjects were the site of active suppuration, and 58 ears in 38 subjects showed scarring or a dry perforation of the tympanic membrane. The audiograms of the cases with unilateral active or healed otitis media showed with four exceptions a hearing loss in the 2,896 to 5,792 c.p.s. frequency range equal in both ears. The hearing for the low tones was either the same in the both ears or diminished by the presence of otitis media. The exceptions just mentioned, two cases of unilateral active otitis media and two cases of healed otitis media, showed greater hearing losses in the 2,896 to 5,792 c.p.s. range in the unaffected ears of from 20 to 40 db.

Peyser (1943) found that the hearing in ears affected by active otitis media was more readily fatigued by experimental exposure to pure tones of high intensity, but Theilgaard (1951) did not confirm this finding and suggested that a conduction deafness due to middle ear disease offered protection to the organ of hearing of workers in noisy surroundings. It was not possible in this study to show an increased susceptibility to damage by traumatic noise of an ear affected by disease but the four exceptions mentioned show that in a small proportion of cases otitis media may afford some protection to the cochlea in the 2,896 to 5,792 frequency range. No opinion is expressed as to a protective effect on the cochlea at the speech frequencies 512 to 2,048 c.p.s. The loss of hearing to these tones is usually more rapid from otitis media than from acoustic trauma although the final result may be less severe.

Recovery of Hearing after Leaving Work

Forty-five per cent. of all the subjects (86 out of 191) stated that their hearing improved after leaving their work. Some noticed the improvement within half-an-hour to four hours. In others the improvement in hearing was less marked and only noticeable over a period of a few days or several months. The subjective improvement in hearing following absence from work was generally more marked during the earlier months or years of a worker's exposure to noise. To obtain an objective assessment of the actual recovery which may have occurred, a few workers were re-examined after a period away from work. The re-examination was made at the start of the work period and before the subject had entered the workshop. Table 4 summarizes the findings.

Apart from two cases (Nos. 4 and 12) there was no significant* improvement after 12 days' rest from noise at either the speech frequencies or in the "C_5 dip". Experimental work indicates that temporary deafness from fatigue of the end organ due to loud tones is rapidly lost, mostly within a few minutes but to a lesser extent in a few hours. As already stated, the first audiograms were made after the subjects had been in quiet surroundings for 20 to 30 minutes. The relatively slight changes

*A gain or loss of 10 decibels is considered to be within the margin of error in pure tone audiometry.

TABLE 4
RECOVERY OF HEARING AFTER ABSENCE FROM WORK

Case No.	Duration of Exposure in Years	Average Loss (db) at 2896, 4098, and 5792 c.p.s.			Average Loss (db) at 512, 1024, and 2048 c.p.s.			Duration of Rest
		On First Test	Re-test after Rest	Gain	On First Test	Re-test after Rest	Gain	
1	1	28	27	+1	16	12	+ 4	62 hours
2	32	83	83	0	40	40	0	62 ,,
3	12	45	45	0	19	15	+ 4	62 ,,
4	14	68	62	+6	33	19	+14	12 days
5	1½	36	36	0	2	5	− 3	12 ,,
6	8	36	32	+4	20	20	0	12 ,,
7	35	71	74	−3	18	19	− 1	12 ,,
8	¼	33	40	−7	8	14	− 6	12 ,,
9	2½	35	27	+8	14	9	+ 5	12 ,,
10	1½	42	39	+3	13	13	0	12 ,,
11	¼	26	29	−3	13	11	+ 2	12 ,,
12	27	55	35	+20	17	8	+ 9	12 ,,

in the majority of the second set of audiograms would appear to confirm this experimental finding and indicate that little restoration of hearing could be expected if the worker were to change to a quiet occupation.

Adaptation of Hearing to Noise

It is a common experience for visitors conducted round a noisy factory to have difficulty in hearing speech. The high level of ambient noise effectively masks the speaker's voice. Yet it is well known among factory managers (who conduct such visitors) that those who spend their working hours in noise can readily hear each other without shouting. It is probable that an ability to lip read plays a part. Thirty-seven per cent. (71 out of 191) of the subjects examined in this investigation were conscious of lip reading during working hours. It was noticeable that in well lit factories where the workers can see each other over the machines, as in the screw factory, 56% (45 out of 79) of the operatives admitted to lip reading at work. Where the standard of illumination was low and the workers could not, by the nature of the work and the machinery, see each other's faces, as among chippers, platers, and stampers, only 20% (26 out of 127) admitted to lip reading. There must be, however, another mechanism whereby the subject can hear speech through the noise. Proof of this was obtained during a visit to a cotton weaving shed containing approximately 1,000 looms in motion. While the ambient noise was not as intense as, say, the heading section of a screw mill, the visitor experienced some difficulty in hearing speech, which was only intelligible when spoken in a raised voice close to the ear. A musical entertainment programme was being relayed during the visit and amplified through loud speakers in the shed. The visitor, by standing close to a loud speaker, was just able to hear the bass accompaniment of the musical composition. The air played by the treble instruments was effectively masked by the noise of the looms. Yet a middle aged female weaver could easily recognize the composition and stated she could hear the words of a song when sung by a soprano voice.

This adaptation of hearing to speech in noise is to some extent lost during periods of rest. Thirty-six per cent. (69 out of 191) of the subjects stated that after two days at the weekend or after the annual 12 days' holiday, they found difficulty in hearing speech for the first half to four hours after beginning work again.

Most of the workmen who had been severely deafened by occupational noise experienced the phenomenon of paracusis willisiana* in the factory but not in other noisy surroundings, such as trains or omnibuses. While it is probable that they could hear speech better in the factory because of a rise in the intensity of the speaker's voice, the ability to hear speech through the noise of their work (also shown by less deafened but seasoned workmen) may well have some effect. It is, therefore, suggested that the phenomenon of adaptation of hearing to speech in noise is of central rather than cochlear origin.

Other Subjective Effects of Noise

Tinnitus.—This was a common complaint. While most workers were free from it at the time of examination, 40% of all subjects (78 out of 191) could remember suffering from it during the early years of their work in a noisy trade. High pitched and ringing, it was always slight in intensity, never caused loss of sleep, and was rarely loud enough to be heard while at work.

Vertigo.—Vertigo induced by noise was complained of by only two subjects, both platers, with

*The ability of a deaf person to hear speech easily in noisy, but not in quiet, surroundings.

normal ears. It occurred when they were inside a small boiler which was being hammered on the outside by heavy sledge hammers by four men. Nausea did not result and the vertigo passed off within a few minutes of emerging from the boiler. Considerable pain was experienced in the ears from the noise, a rare complaint amongst workers in noisy occupations.

Poor Concentration, Headache, or Irritability.—None of these ascribed to occupational noise was often complained of and was more usually due to dissatisfaction with the nature of the work or other extraneous factors. It was well recognized among the foremen that if a workman objected to the noise of the work, he would soon change to a quieter job. A high proportion of new hands left such noisy work from this cause, but if the worker could persist at the work for a week or two, acclimatization usually took place. The subject was then able to ignore the noise and found it neither irritating nor unpleasant. In fact many stampers found the noise of their trade soothing.

Awareness of Risk of Occupational Deafness.—With few exceptions, workers in the boiler-making and stamping trades were aware of the high incidence of occupational deafness, but were not apparently perturbed by the prospect. The insidious onset of deafness which resulted in a man being unaware of the degree of his hearing loss and the relatively high proportion of old hands with serviceable hearing engenders a spirit of *laissez faire*. The wearing of protective devices in the ear was observed only in the boiler-making trade. Even here in the noisiest section (the chippers) only four out of 14 men habitually wore wool plugs for the express purpose of protection from noise. In the same group no less than three men merely inserted the plugs to prevent the ingress of dust. Out of the remaining 50 boiler-makers who were examined, only six habitually wore wool plugs.

Prevention of Occupational Deafness

The ideal remedy for the prevention of occupational deafness would be to eliminate injurious noise at its source. Improved designs of machines and their mountings have already done much to help. Technical advances in the method of manufacture may diminish noise but the reverse is often the case. For example, the electrical welding of steel plates, which is to a limited extent supplanting the lapped riveted joint, necessitates the extremely noisy process of chipping. The reduction of noise at the source has thus only limited possibilities. The reduction of reflection and reverberation of noise by sound proofing surfaces and erecting baffle walls have in certain instances been effective, but again scope is limited.

There remains a third alternative, the acoustic insulation of the worker's ear by wearing a protective device. Two main types have been described, the meatal plug and the ear "muff". The former may consist of dry cotton wool (commonly used but of little value), cotton wool impregnated with vaseline or "plasticine", or rubber. Vaseline impregnated cotton wool is stated by Fowler (1940) to produce a relatively constant attenuation of 20 db for frequencies below 1,000 c.p.s. and 30 db for frequencies above 1,000 c.p.s. Of the numerous types of rubber ear plugs, the V–51R ear warden provides an acoustic insulation of 25 to 30 db or more at the high end of the audiometric frequency spectrum (Taylor, 1947). An example of the second type of ear protector is the Rüedi defender (Rüedi and Furrer, 1946). Designed primarily for use by gun crews, it consists of a metal box with a rubber flange on the edge fitting closely to the head and covering the whole of the external ear. The outer wall of the box is perforated by several fine holes. The size of the holes and the capacity of the box are calculated to the desired resonance, frequency, and damping. The damping reduces the steepness of the front of the sound pressure wave and also the maximum pressure amplitude operating on the ear drum. The hearing loss obtained when the defender is worn is insignificant at the middle and lower frequencies but above 2,000 c.p.s. amounts to 25 to 30 db. An experimental test of the Rüedi defender on several subjects with normal hearing under the noise conditions of a boiler shop showed that considerable aural fatigue from noise occurred when the defender was worn.

Both types of protective device have their disadvantages. The meatal plug, while giving a high degree of protection, is unsuitable in cases of otitis media or otitis externa. It may irritate the meatal skin, particularly in hot and dusty trades. Repeated insertion will drive plugs of wax further into the meatus. It may allow noise to reach the ear unless correctly adapted to the shape of the meatus, particularly where the meatal canal is oval in cross-section. It is liable to cause discomfort when worn regularly for long periods. Owing to its small size a rubber plug is easily lost and must be regularly cleansed to avoid the risk of infection. The Rüedi defender has none of these disadvantages except that in very hot occupations excessive moisture will accumulate inside the box and may exacerbate a pre-existing dermatitis. In the boiler-making and

ship-building trades, where the wearer often has to work in a confined space, some modification of the head band would be necessary to allow for the wearing of a protective cap.

The Rüedi ear defender was designed to allow the hearing of speech. Although necessary for a gunner, a workman in a noisy factory only occasionally needs to hear spoken instructions. When the fine holes of the defender are occluded by a layer of " plasticine " a considerable improvement in the sound occlusion results and little aural fatigue is caused on exposure to loud noise. In view of the previously mentioned advantage of the box type of defender over the meatal plug it would seem desirable that further experiments should be carried out with ear " muffs " of various materials.

Conclusions

Minimum Values for Harmful Noise.—Table 1 shows that a larger proportion (26 out of 49) of the men employed in chipping, riveting, stamping, plating, and heading became deafened to speech at more than 3 feet after 20 years' exposure, whereas of those engaged in worming and turning, only one out of 13 of the former and none out of 24 of the latter are deafened to a like degree. In the heading section four out of 14 men were so deafened.

Although the size of the samples in each of these groups is small it would appear that the risk of damage to hearing is considerably greater in the heading section than in the worming section. The noise level measurements in the heading, worming, and turning sections vary from 100 to 112 phons. It would appear therefore that noises of an intensity of 100 to 112 phons represent the border line between that which is harmless to hearing and that which is harmful to an appreciable proportion of subjects.

It is therefore suggested that it is only when the overall noise level exceeds the region of 105 to 108 phons that serious damage to hearing is likely to occur in an appreciable proportion of the population exposed. Noise less intense than 105 phons will probably cause damage only to the hearing of the most susceptible subjects.

Prevention of Occupational Deafness.—Mention has already been made of the limited possibilities of the reduction of noise at its source or by reflection or reverberation. Where reduction to harmless levels cannot be effected by these means, the ears of the individual worker must be protected. Furthermore, the degree of protection must be related to the intensity of the noise level in which he works and the susceptibility of the particular individual.

When the intensity of the noise is more than 105 to 108 phons, protective devices should be worn by all workers. As pointed out by Perlman (1945) a device which gives an insulation of 30 db when worn in an ambient noise of 120 db will probably reduce the noise reaching the cochlea by 30 db, e.g. to 90 db. An additional protection of, say, 15 db will be required for safety. Hence a protective device with an insulation value of 30 db will be adequate for the worker in a noise of 110 db but will fail to give adequate protection at a higher noise level of 130 db.

The average workman is notoriously careless in the use of safety devices, particularly where these are provided to prevent uncommon accidents or disease of delayed onset. Thus MacLaren and Chaney (1947) found that of a group of workmen provided with ear defenders, only one third used them regularly, one third used them occasionally, and one third discarded them soon after issue. Education of the workman on the risks involved and official recognition by legislation would doubtless effect improvement.

Any form of ear defender worn by the worker whose hearing is very susceptible may be inadequate to prevent loss of hearing if he works in very intense noise. Furthermore, such a susceptible individual working in a source of noise of less than 105 phons (but probably of more than 90 phons) will, if he is to continue in such work, require protection. To discover such susceptible individuals in any occupational group at risk before permanent loss of hearing results, it will be necessary to devise a reliable pre-employment test for susceptibility. Failing this, such individuals should be weeded out in the earliest stages of their deafness before permanent loss of hearing results. Theilgaard (1949) suggests that previously described tests are likely to be unreliable, so, for the present, reliance must be placed on the latter method.

Grove (1949) presents the views of the Sub-Committee on Industrial Noise of the Committee on Conservation of Hearing set up by the American Academy of Ophthalmology and Otolaryngology. He recommends that every workman engaged in a job where the noise level exceeds 90 db should have a pre-employment audiometric examination and be re-tested after one week and subsequently at stated intervals. Any workman who complains of tinnitus after working in a noisy environment should have his hearing re-tested. If on any of these re-tests it is found that an average loss of 10 db at 3,000 to 6,000 c.p.s. has occurred, he should be forced to wear a protective device or be transferred to a less noisy job.

Summary

A report is presented on an investigation into the hearing of 219 men and women employed in several noisy engineering trades. Twenty-eight workers were found to be suffering from bilateral ear disease or deafness not due to noise. Of the remaining 191, all except one man were found to have hearing losses due to noise which could be demonstrated either by speech or pure tone audiometric tests. The tests were carried out at the factories during working hours.

After 20 or more years' exposure to the noise of their work, nine out of 12 chippers and riveters, seven out of 11 stampers (drop forgers), six out of 12 boiler plate fitters, and four out of 14 heading machine operators who were examined were unable to hear speech at more than 3 feet distance in either ear.

Reference is made to noise level measurements observed by the Physics Department of the National Physical Laboratory in the factories where the hearing tests were carried out. Figures from their report suggest that only when the overall noise level exceeds 105 to 108 phons is serious damage likely to be caused to the hearing of an appreciable proportion of the workmen. Noise less intense than 105 phons will probably cause damage to the hearing of only a small group of individuals most susceptible to injury.

Observations are also made on the recovery of hearing after a period of rest from work, the phenomen of adaptation of hearing for speech in ambient noise, and other subjective effects of noise.

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AGE AND INDUSTRIAL ACCIDENT RATES

BY

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During the last 50 years, and especially since the first world war, much work has been carried out on the causes and results of industrial accidents, but until Newbold's study (1926) few attempts had been made to separate the various possible direct influences of ageing. From her work and from that of later investigators has come the current view that the accident rate declines steadily as age advances, though not all of the relevant studies support this view and some appear to contradict it. In this review we have attempted to show that at least some of the differences of interpretation appear to be due to the methods of recording used or to the types of work studied, and it is possible that some of the anomalies could be explained if data were suitably collected.

Survey of Previous Studies

The work done before 1926 has been summarized by Newbold (1926), and generally indicates a fall in accident frequency with age. Newbold collected records of accidents occurring in many departments in 22 factories, the data for each department being kept separately. In every group, except one of young women, there was a downward trend with increasing age, although in a few instances workers over 60 showed a slight upward trend. The relative effects of age and length of service were measured statistically and age was shown to be the more important; there were, however, few new employees in the groups. The work of Vernon and Bedford (1928), and of Vernon, Bedford, and Warner (1931) on compensated accident rates for several thousand coal miners demonstrated a rise in frequency at ages above 40 for coal face workers, but a peak rate in the under-20s for other underground men. Barkin's study (1933) of 282 compensated factory accidents showed a decline in frequency as age advanced, but there was a slight rise at ages above 60.

Vernon (1936) quotes various studies supporting the view that accident frequency declines with age, but shows that rates are much affected by the inexperience of new workers. Kossoris (1940) examined disabling and compensated injuries in several large communities. In the main there was some tendency for frequency to decline with age, but in one community where exposure was equated for all age groups the frequency was lowest in the 35–39 group and rose with age thereafter. Data collected from 700,000 households relating to non-fatal industrial accidents which had occurred in the previous 12 months were used by Klebba (1941) to demonstrate that the frequency of accidents causing more than six days' absence declined with age among non-manual, but increased markedly among manual, workers.

Mann (1944), observed a decline in frequency of all reported accidents with age among males at an ordnance depot but a rise above the age of 35 among females. Whitlock and Crannell (1949) were unable to demonstrate any significant age difference between 100 steel workers who had major accidents and an accident-free control group. Sutherland, Harris, and Smithers (1950) demonstrated a decline with age in the frequency of all accidents reported to the first aid posts among 4,000 factory workers, the decline being marked up to 25 and more gradual at higher ages. The rate for all employees at a motor works was at a maximum in the 25–34 group and declined rapidly at ages above 45 (Paviere, 1951). However, Heinrich (1950) concludes that although the studies he reviewed indicated a fall in accident frequency with age, the available data have serious limitations.

Newbold (1926) also gave various figures relating to the duration of disability resulting from accidents and the fatality rate and these indicated a consistent increase with age in both instances. Brundage (1927), who studied 2,200 male electrical workers, found that among these the number of days lost per absence as a result of accidents at

work increased with age, but that the annual number of absences per 1,000 workers was around 80 for all age groups except the over-55s, for whom it was only 56. A number of later studies have also confirmed the finding with regard to length of disability, among them being those of Vernon and Bedford (1928), Stevens (1929) for some 5,000 compensation cases, Vernon and others (1931), and Klebba (1941). Using three separate sets of data, Kossoris (1940) showed that the frequency of deaths and of permanent impairments per 1,000 injuries, as well as length of disability, increased with age. In a later paper Kossoris (1948) reports that among 18,000 factory workers the frequency of disabling injuries was not related to age, but the frequency of non-disabling injuries showed a steady decline from the 25–29 age group upwards.

It will be seen that there is general agreement as to the effect of age upon the severity of injuries incurred through accidents but the effect on accident frequency is much less certain, and so the remainder of this article is primarily concerned with accident frequency.

Criterion of Accidents

The authors surveyed base their arguments not on the incidence of accidents as such but on the incidence of accidents which led to injuries. While this is perhaps inevitable for practical reasons, not only is there no account taken of those accidents which result only in spoilt work with no injury to the operator, but the differences in criteria of what constitutes an injury make it not only difficult but hazardous to integrate the results of the various studies in a meaningful fashion. For instance, data based on compensated injuries are likely to be complicated in the following ways. (1) A fixed duration of absence from work following injury is required to qualify the worker for compensation, and the duration varies from one country or state to another. Also, since older workers take longer to recover than do younger workers, a given physical injury is likely to produce more cases of compensation amongst older workers. (2) There is likely to be selection in favour of large organized industries and at the expense of workers and bodies not covered by the Workmens Compensation Acts. This point has been commented upon both by Kossoris (1940) and by Klebba (1941), the latter obtaining from an analysis of U.S. Public Health Survey data results which were at variance with those given by State agencies, sick benefit organizations, and insurance companies, and attributed the difference to the limited coverage of compensation sources. (3) The various age groups are not usually equated for exposure in terms of the length of time they were actively employed during the period of the study.

While statistics relating to serious injury are open to question on the grounds of the statutory requirements for their inclusion in compensation data, statistics of minor injuries, unless they are very carefully collected may, as both Newbold and Sutherland and others (1950) have pointed out, be incomplete when they relate to older workers.

A study of visits to factory health clinics for the relief of minor aches and pains—headaches, colds, digestive discomforts—shows a peak in the late 20s and early 30s followed by a steady fall in the number of attendances with age (Kossoris, 1948). Colds, bronchitis, indigestion, and biliousness have, however, been held to increase with age from the early 30s, while the incidence of headaches reaches its peak about the age of 35 (Fig. 1), and varies

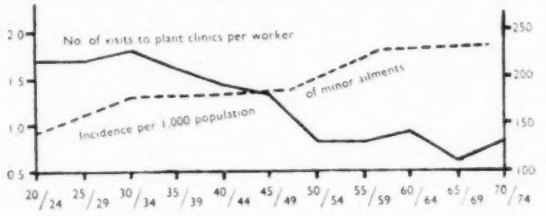

FIG. 1.—The continuous line represents number of visits to plant clinics per worker, on account of minor bodily ailments; the broken line represents the incidence per 1,000 population of colds, sore throat, bronchitis and chest colds, indigestion, and headache (Collins, 1935).

little till the age of 60 (Collins, 1935). Assuming that the two samples are comparable as regards physical conditions, this finding suggests that some minor bodily discomforts which are reported by younger people are not reported by older. This may be because of fear of discrimination; because of a gradually formed indifference to lesser pains built up over many years' experience of injury; because of a possible tendency for persons to report only the first or the first few minor injuries; or because of possible differences in the outlook of earlier generations towards industrial hygiene. Whatever the reason, it is apparent that the subjective attitudes of people in different age groups ought to be taken into account when interpreting accident data based on systems of voluntary reporting.

Occupation

If the current criteria of what constitutes an accident leave much to be desired, the tendency to collect data on accident rates without reference to specific occupations may be equally misleading.

When, as is often the case, data from a number of factories, or even from many jobs in one factory, are pooled to give a table of accident rates at different ages, a decline in rate with age could as easily mean that older people are engaged upon less hazardous jobs as that accident liability decreases with age. There are, in fact, a number of strong indications that the age distributions of employees in various occupations do show considerable differences. Evidence was provided by Vernon and Bedford (1928) for coal miners, and for numerous occupations by Belbin and Sewell (1949), a summary of whose work is given by Welford (1951). The latter investigators further show that at least some of these differences are characteristically related to the requirements of the job.

The figures given by Mann (1944) show the wide variation with occupation in the number of accidents per person among workers at an ordnance depot (Table 1). Unfortunately, the data available are

TABLE 1

ACCIDENTS PER PERSON IN DEPARTMENTS OF AN ORDNANCE DEPOT CALCULATED FROM FIGURES GIVEN BY MANN (1944) FOR A FOUR-MONTH PERIOD

Department	No. of Men Employed	No. of Accidents per Person
Surveillance and renovation	30	1·567
Magazine area	743	0·662
Combat equipment	165	0·636
Firemen	71	0·450
Utilities	349	0·449
Motor transportation	165	0·321
Railroad transportation	112	0·250
Others, administrative	244	0·246
Guards	164	0·207

insufficient to indicate whether these differences in liability are associated with the age of the workers. However, Stevens (1929) pointed out that a large number of low-hazard occupations such as those of watchman, sweeper, and so on, were mainly filled by men over 50, and Klebba (1941) also remarked upon the influence exerted on accident frequencies by this tendency for older workers to occupy low-hazard jobs.

Any attempt to assess the influence of age on accident rates, using a mass of data collected from many operations, ignores such differences in age distribution related to the degree of accident hazard and by-passes the important question of selective influences in the production of the age-structure of a working population under study. The study by Newbold (1926) appears to stand alone in that particular care was taken to choose departments where all the employees were on the same type of work, even if this involved restricting the study to one or two departments in a whole factory, and separate rates were calculated for each department. Even so, there are still difficulties : the samples of workers obtained by this procedure included only a small number of older people ; secondly, as Heinrich (1950) has observed, there may still be small differences in the work done, and important differences in the design of the machines or in working conditions. It is impossible to say at present how far these points are in fact of importance in the study of age variations in accident rates : what is clear is that the subject demands a detailed approach rather than attempts at an overall assessment.

Age and Experience

The first attempt to measure the relative contribution of age and experience as determinants of accident liability was made by Newbold (1926). The partial correlations which she calculated showed that when age was held constant the original association between length of service and accidents almost disappeared, but when length of service was held constant, the association between age and number of accidents remained almost unchanged. By contrast, Ghiselli, Brown, and Minium (1946) in a survey of street car motormen in Chicago found that when experience was held constant, the relationship between accidents and age was practically zero.

In criticizing Newbold's results, both Newbold herself, and later Vernon, pointed out that experience in this case only referred to the time spent in that particular factory, and not to any previous experience elsewhere ; also Newbold's samples contained very few new entrants, who show a high accident rate, and, as Vernon has pointed out, are largely responsible for her negative relation between accident rate and experience. In fact the data relating to length of service surveyed by Vernon (1936) make it fairly clear that the relation between experience and accident rate is more properly a relationship between " lack of experience and accident rate ". With increasing experience the accident rate falls rapidly at first—possibly while the job is being learnt—and varies comparatively little thereafter. The accident rate then, is likely to be dependent upon the rate of labour turnover. Where this is low, and there are few new entrants, it is probable that there would be relatively little relationship between experience and accident rate, particularly in a short-term study. Conversely, where one finds an equally high rate of turnover amongst all age groups, one would expect also to find in a short-term study a very strong relationship between accident rate and experience, and little relationship with age, once experience was partialled out. This kind of relationship might be

able to explain the apparent contradictions between the results of Newbold, and of Ghiselli, Brown, and Minium, but the published data are unfortunately not sufficient to say definitely whether this is so.

In a large scale survey the general effect of this relation between inexperience and liability to accidents would be to increase the accident rate of the younger age groups, both because they have the greatest number of new entrants, and because it has been claimed that younger age groups tend to have a greater turnover than older (Kitson, 1925; Greystoke, Thomason, and Murphy, 1952). Thus in terms of apparent safety the older would have an advantage over the younger; on the face of it, due to the result of their greater age but in reality due to the effects of labour turnover causing lack of experience in the younger age groups.

A further difficulty in the assessment of the relative roles of age and experience is, as has been contended by Ghiselli and Brown (1948), that the more experienced groups of workers may have been selected in terms of the safety of their performance. Such selection, it is claimed, would prevent compliance with the basic assumptions of the partial correlation method. Certain employees may be moved, by the firm or at the employees' own request, on to other work on account of inability to perform the task, or of incurring a high accident rate, while, for various reasons, other employees may leave the industry altogether. Apart from this it must be remembered that accidents themselves are taking a yearly toll of workers from industry in permanent injuries or deaths. Though it is possible that this gradual elimination may act impartially, if it is true that some people are more accident prone than others, it is likely that these will be removed and that those who will be left will be those who have fewer accidents.

General Physical and Physiological Conditions

Besides the many problems involved in the collation and analysis of data, in such studies some attempt should be made to assess the importance of the interrelation of various changes in the human organism that occur with age with characteristics of the working environment, by themselves neutral, but in terms of these changes, inimical.

Though it appears that some impairment in function may occur with increasing age without causing an equivalent impairment in performance (Welford, 1951), deterioration beyond a certain point will clearly render many tasks either impossible or highly dangerous. Thus many of the functions which would be supposed to be necessary for efficient driving skill begin to decline either in the early 30s or before, while safety in terms of millions of miles driven per accident is low in the 20s and reaches a peak somewhat later, at the age of 45–50. Beyond this age, however, the road accident rate increases with age very rapidly (DeSilva, 1938). One example of a deteriorating function which may be involved in this increase is that of visual performance. Thus Selling (1944) found that of 35 accident-prone drivers over 65 years of age, all had imperfect vision.

The relation of visual defects to accident rates in a general industrial sample has been shown by Kuhn (1943), and the enormous quantitative increase in visual defects with age has been shown by Mayer (1937). How far these findings are related is of course speculative, but there appear to be good reasons for supposing that a study of accident rates related to deteriorating visual ability might be fruitful. Visual acuity decreases in older people (Weston, 1948) but it is also dependant upon the degree of illumination in which the stimulus is exposed. Poor illumination, which would therefore adversely affect older people, might result in their exposing themselves to a greater hazard when working on grinding or turning processes, since "accidents due to foreign bodies—such as metal particles and emery powder—getting into the eye were found to be especially influenced by lighting, apparently because the workers tend to bend nearer their work when the light is poor, and so expose their eyes more freely" (Vernon, 1936).

It is important to recognize here that the so-called visual defects of older people may be of two types: defects of peripheral organs and central defects of perception. Only the first kind would be revealed by physical examination of the eye.

Effects of Fatigue.—Vernon and Bedford (1928) showed that accident frequency increased with age among miners, and concluded that this was probably due to the arduous nature of the coal miner's work. A later study (Vernon and others, 1931) showed that the relationship of accident rate to age varied with the temperature conditions under which the miners worked. At temperatures below 70° there was a general tendency for the accident rate to fall with age; at temperatures over 70° there was a marked rise with age from 35 years of age upwards. Vernon (1936) interpreted these findings in the following words:

> "Accidents tend to diminish with age because the older men are more skilful and more careful than younger men, but on the other hand they are more easily fatigued, and fatigue may lead to accidents."

In support of this view it should be pointed out that Vernon and Bedford (1928) found that the increase in the accident rate of the older age group

was greater in the years 1927–28 when an eight-hour shift was worked than during 1923–24 when a seven-and-a-half-hour shift was worked. Such research as there is on the relation between fatigue and age (Simonson, 1947) confirms Vernon's view that older people are more susceptible to muscular fatigue than younger, while the greater depression of fusion frequency of flicker attributed to older subjects after tiring exercise (Simonson, 1947) suggests that some psychological functions may be more affected by fatigue as age advances. Whether age brings an increased susceptibility to mental fatigue which might affect the capacity to make judgments or anticipate contingencies is a question that requires investigation.

Falls and Lapses.—Sheldon (1948), in a survey of old people living in Wolverhampton, stressed the appearance in old age of such symptoms as vertigo and sudden falls. Statistics of falls, such as are contained in the reports of the Registrar General of England and Wales and in the public health reports in the U.S.A., all show a very marked rise in frequency in the older age groups. Where risk of falls is present either because of slippery floors or the use of raised surfaces or ladders, the accident rate for older people is likely to be increased, and the accidents sustained likely to be more severe (Fig. 2).

TABLE 2

ANNUAL LOSS OF TIME PER PERSON ON A FACTORY PAY-ROLL AS A RESULT OF WORK ACCIDENTS COMPUTED FROM DATA BY BRUNDAGE (1927) FOR 1922–24

Age Group	15–24	25–34	35–44	45–54	55 and over
Mean annual days of disability ..	0·992	1·336	1·483	1·964	1·867
Number of persons	520	710	541	311	141

Length of Absence

The general agreement on the increase in the severity of accidents with age indicates that the liability involved in the employment of older workers cannot be expressed in terms of accident frequency only. Even if there is a fall in the accident rate with age when the variable factors discussed earlier are eliminated, this may be outweighed, in terms of total time lost, because of the longer absence per injury of the older workers. This point is illustrated by Brundage (1927), who calculated the annual loss of time resulting from accidents at work as a rate per employee of the factory concerned (Table 2). Table 2 shows a general increase with age in the

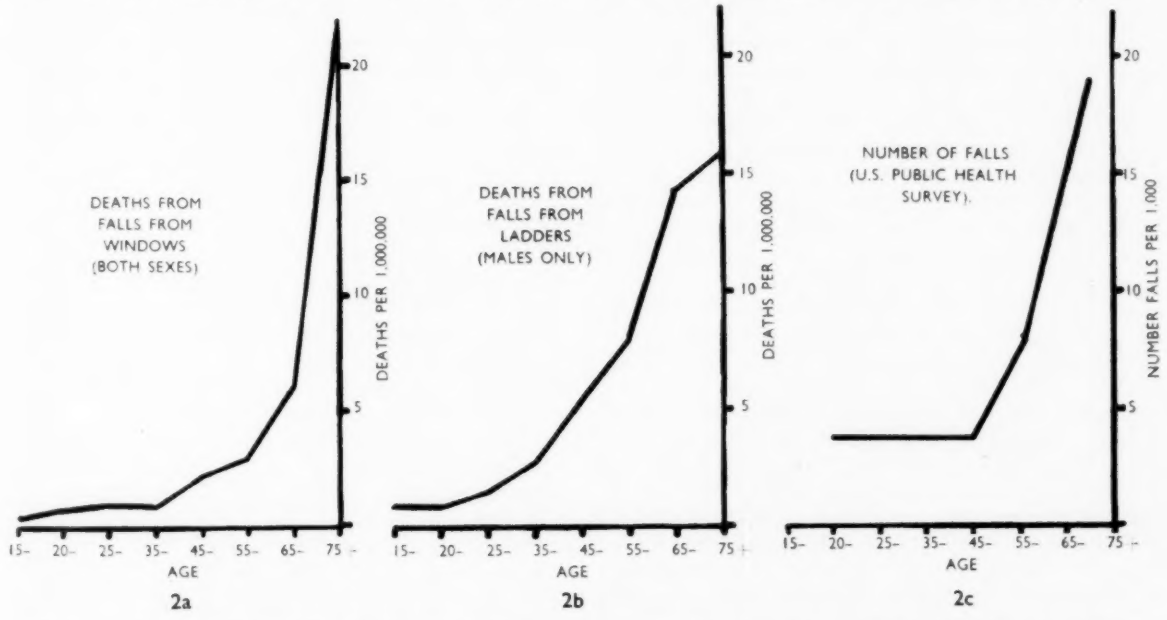

FIG. 2.—Fig. 2 shows (a) deaths from falls from windows per million of the population at that age, both sexes, and (b) deaths from falls from ladders per million of the population at that age, males only. (Females only constituted 7·8% of the total deaths from falls from ladders.)

These figures are arrived at by averaging the number of deaths from these causes for the years 1946, 1947, and 1948 as given in the Registrar General's Statistical Review of England and Wales for these years, and stating them in terms of the average population at each age for this period.

Fig. 2 (c) shows the number of falls reported per 1,000 of a sample taken in each age group in the U.S. Public Health Survey (Collins, 1935).

time lost, although permanently incapacitating injuries and deaths, whose incidence is known to rise with age, are excluded.

From the standpoint of time lost, changes in the severity of accidents with age need to be seen in the context of general health changes, and of the time lost from all health causes. Older persons lose more time through all sickness causes than do young workers (e.g., Roberts, 1951), but the actual proportion of time lost due to accidents as against other reasons appears to be fairly small, perhaps about 10% (Vernon, 1920; Padley, 1947). Although this relationship may change to some extent as a result of improved methods of medical treatment and extended health services, the greater the age disparity of sickness rates, the greater will be the difference in the amount of exposure to risk of accident.

Type of Injury

From the data on 5,000 compensation cases given by Stevens (1929) it is possible to calculate the proportions at different ages of certain grouped types of injury. The proportion of cuts, punctures, and lacerations (1,711 cases) is seen to fall steadily from over 50% in the 15–19 group to 25% in the over-60s, while the proportion of schedule losses * (707 cases) rises from 8% in the youngest to 28% in the oldest age group; there are no significant trends among the remaining injury groups. Barkin's (1933) study of compensated accidents showed a steady decline with age in the proportions of cases of crushing injuries, cuts and punctures, and lacerations. These declines he attributed to increased mastery of tools and greater care among the older workers, while brittleness of bone is suggested as the explanation of a rise with age in the proportion of injuries due to fractures. The proportion of bruises increased markedly at age 33 while that of burns and scalds decreased.

Padley (1947) observed a striking increase with age, particularly at ages above 45, in the proportion of fractures incurred by single women, although the men showed no significant increase. Possible explanations suggested were a higher occupational risk, due to selection of types of work among the older women, or a generalized physiological sex difference, perhaps related to the menopause. Whatever the real reason, the possible role of occupational hazards as determinants of types of injury incurred cannot be ignored. Clearly there is a relationship between the type of work and the most likely kind of injury as a result of an accident. An example is quoted by Newbold (1926) who found that in making tin boxes accidents arose mainly from contact with sharp edges of the tin.

From these studies it would appear that the liability to incur certain types of injury or to be prone to those accidents which tend to produce particular kinds of injury, does in fact vary with age, but the findings are insufficiently established and further work is needed.

At present, how far this kind of variation is due to changes in the individual and how far to occupational factors, is uncertain. When deteriorative changes in the individual coincide with adverse occupational factors under a particular set of working conditions a situation arises which is likely to prove very unfavourable to the older worker. An example is the case of an employee with deteriorating eyesight engaged upon work where clear and rapid vision of the machine's movement is essential to avoid injury to the fingers. On the other hand, if specific safeguards are found to be necessary to protect older workers from a particular hazard, this would be likely to have a good effect on the accident rate of all workers, even if the relative effect varied with age.

Discussion

Behind the majority of studies there seem to lie two assumptions; (1) that there is a general age factor in accident causation, and (2) that the effect of this is seen in the accident rates calculated from compensation data or factory records.

It is hoped that the complications, for which adequate allowance has not always been made, involved in any attempt to obtain valid information from these sources have been indicated. In general, this subject calls not for the collection of massed data but rather for a more detailed approach, taking into account differences in the age-distribution of workers on different jobs, the effects of selection, the work history and experience of individuals, standards of reporting, and the types and degree of hazard of the work.* Unless this is done, it is very difficult to say how far the calculated rates for different ages do represent the direct effects of ageing.

The generally observed decline with age in accident frequency has usually been attributed to increased experience, or greater carefulness, among the older workers. Newbold (1926) noted that it was "a generally accepted opinion that older people are more careful than younger ones", and also drew

* Certain serious injuries which had been standardized for "days lost" by the Compensation Board regardless of the actual time needed for recovery.

* Basically the problem is that of control of length of exposure; the information mentioned is necessary if this is to be adequately achieved.

a distinction between " general immaturity " and " unfamiliarity to a particular job ". Sutherland and others (1950) suggested, among other things, that older workers had developed greater responsibility, while Mann (1944) claimed that the effect of monotony was greater among youthful workers, and Barkin (1933) commented on the older workers' greater capability in handling tools. While these points are general and not the results of a full analysis, they do express common opinions regarding changes with age which could be supposed to have an effect on accident liability. It is both possible and desirable to examine these suggestions in greater detail.

First, studies often show a very high number of accidents occurring among the under-30s compared with the rate in persons of higher ages, among whom there may be very little change. Although such a frequency distribution might give a negative correlation of accident rate with age, this would be due more to the deleterious effect of youth than to the beneficial effect of a continuous ageing process. The very high accident rate commonly found among persons who are in their first few months at a job indicates that lack of experience of the work is largely responsible for an excess of accidents among the young, but also involved may be general personality factors, such as would appear to be included in the concepts of " general immaturity " and " less responsibility ". An interesting link with this is Banister's enquiry (1938) into accident causation ; he listed eight main causes, among which were the meeting of a slightly novel situation in a maladaptive way, and the taking of realized risks through bravado or laziness. He comments that the latter is more common among younger workers. The longer a worker has been engaged upon an operation, the more likely he is to have met the possible variations of the normal situation and to have found appropriate ways of dealing with them. Young workers will have had less time to experience such variations, and the effect of this is the greater because of the relatively high rate of labour turnover among young employees (Kitson, 1925 ; Greystoke and others, 1952). It is also to be expected that, provided a person has capabilities sufficient to meet the demands of the job, as time goes on he will become more proficient through the refining of performance to meet those demands to the point of his maximum efficiency, whether the limit be imposed voluntarily or involuntarily.

Various studies, such as those reported by Welford (1951), of performance at a variety of tasks have shown that, where possible, older people take more time over each item of a task, so that in a given time they get less done but make proportionately fewer errors than younger persons. However, where performance of a task is under pressure, whether imposed by the nature of the task or constrained by the experimental instructions, older persons seem to be at a disadvantage. While it would be hazardous to transfer this finding to industry without further confirmation, since the execution of a new task for a limited time is not necessarily indicative of performance in a familiar and long-practised job, support is forthcoming from the observations made in industry by Belbin and Sewell (1949) and summarized by Welford (1951). It is perhaps also supported by the long-known fact that at times of heavy production there are often increases in the numbers of accidents, though the relative importance of the taking on of new employees and of the speed-up of work has not been determined. Although direct evidence is lacking, in situations where the worker has to keep up with a rigid time-cycle imposed by the machine, or, for other reasons, has to work at an uncongenial speed, there may be a tendency for accident frequency to rise with age.

Decline with age in various bodily functions seems likely to exert an unfavourable influence on accident liability. Where the level of a person's capabilities is reduced below that required at some stage of the work, the scene is set for a deterioration or failure in performance. The reduction of the level of capability may be very gradual and may for a time be overcome by various forms of compensation, or by the expenditure of increased effort. Eventually there may come a point at which the organism can no longer meet the demands of the situation, or can normally do so but a sudden variation or the gradually accumulating effect of fatigue causes a breakdown of performance.

Furthermore, there are also many accidents, such as falls, herniae, and those arising from " blackouts " which are not failures of performance, although they may occur in conjunction with failures of performance. As the frequency of accidents of this kind rises, often steeply, with age, the effect on the statistics of all types of accidents is to the disadvantage of the older employee.

There are, then, many factors influencing accident rates, the effects of which will vary with circumstances. Since some of these factors favour the older person and some the younger, we cannot expect that the relation between age and accident rate will always be the same. If the contentions of this article are correct, the picture which presents itself is that of two opposing tendencies : on the

one hand, the effect of experience, greater carefulness, and so on, becoming more pronounced with age and so tending towards a lower accident rate among the older workers; on the other hand, the biological decline of the organism as age advances. The resulting interplay issues as the observed accident rates for different ages.

In between the young and old age groups is one in whom the physical decline has not proceeded very far, but yet have considerable stability and experience and could be expected to have a lower accident rate than those at either end of the age scale. The exact shape of the accident curve will vary according to the nature and stresses of the job and the working conditions so that the older workers may have a more or less favourable accident rate according to the circumstances.

Such a picture might account for those cases where increases in accident frequency with age have been shown, as by Vernon and others (1931), since the particular sets of working conditions might have been such as to overtax the physical capacities of the older men. However, the production of more adequate statistics through a system of accident recording such as that suggested by Whitfield (1950) is essential if further light is to be thrown on this problem. An adequate record would provide information on the person injured, including occupation and department, what he was doing at the time of the accident, and the time and place of its occurrence. Objects, if any, causing the injury should be noted (a standardized classification of objects appropriate to the occupation is suggested), together with any other circumstances, such as slipping or falling, or the action of a second person. The record should also include details of the nature and location of injury, and the time lost as a result of the accident.

While this information gives as complete a picture of the accident itself as can be obtained from a record, it is not sufficient as a basis for the study of age variation. This requires the maintenance of additional records relating to ages and occupations, length of service and, so far as is possible, details of the work done while employed, and before being employed, in any particular organization for all employees and not just those who have an accident. Furthermore, details of absenteeism, whether from sickness or other causes, would enable corrections to be made for variation in the time spent at work. While the requirements listed may seem to demand a large volume of work, it may be observed that much of the information needed is often already collected under various guises, and modifications of the present system of collection might be all that would be necessary. The data provided would then permit a study of the relation between age and accident rates which at least made a more adequate allowance for the attendant circumstances than do existing studies.

Summary

The methods and results of investigations into the relation of age and industrial accident rates are surveyed and discussed. It is argued that the data at present available have serious limitations and do not permit definite conclusions as to the nature of this relationship. A detailed approach, including the collection of a number of items of information about each accident, is suggested as a prerequisite of further progress.

The authors wish to thank Professor Sir Frederic Bartlett and the Director of the Nuffield Unit, Mr. A. T. Welford, for valuable criticism of this paper.

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* The use of test scores for the prediction of accidents of streetcar motormen.

OBITUARY

AIR VICE-MARSHALL SIR DAVID MUNRO

K.C.B., C.I.E., LL.D., M.B., F.R.C.S.Ed.

We regret to announce the death of Sir David Munro on November 8, 1952, in his seventy-fifth year.

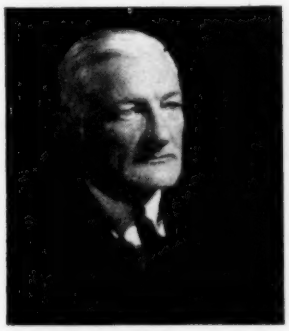
David Munro came officially into industrial medicine at the age of 52 when he succeeded D. R. Wilson in 1930 as Secretary of the Medical Research Council's Industrial Health Research Board. He admitted in his autobiography, " It Passed too Quickly ", that his knowledge of industrial health was very limited, but his experience as Director of the Royal Air Force Medical Service, his personal charm, and administrative ability were much needed qualities in a man who was to be the link between a scattered group of research workers and a board of doctors, scientists, employers, and trade unionists with such diverse interests in the health of workers.

After graduating at Edinburgh University in 1901 he joined the Indian Medical Service. In the 1914-18 war he served in France, Mesopotamia, and Palestine and was appointed C.I.E. for distinguished service at Basra. After the war he transferred to the Royal Air Force and in 1921 became Director of Medical Services until he retired in 1930. It was in this post that he probably made his greatest contribution to medicine. He built up a medical branch which has served the Royal Air Force with distinction. Not least of his achievements, of which he later spoke with justifiable pride, was his ability to pick good men, the creation of a first class nursing service, and of a medical team which was able to deal with the special problems of flying. He had indeed applied sound principles of industrial medical practice to a fighting service.

He was Secretary to the Industrial Health Research Board at a time of economic depression when much of its best work was done silently and unnoticed. But these investigations have since received fuller recognition and it must have given him much pleasure when in the last months of his life several of the old I.H.R.B. pink reports were re-published after being out of print for many years. Later, when Britain began to prepare for war, Munro was more concerned with the application of the results of research than with the initiation of new research. He took to heart that section of the Board's Terms of Reference by which they were empowered :—

" To take steps to secure the co-operation of industries in making widely known such results of research work as are capable of useful application to practical needs."

The results of the first 20 years work of the Board



were well reviewed in its eighteenth Annual Report; special attention was drawn to such of the results which had already found a place in industrial practice or were ripe for practical application. Early in 1940 the Board published " Industrial Health in War ", which was a summary in simple terms of the research findings capable of immediate application and furtherance of the national effort. This policy inspired by a practical man was a wise one to follow in the early days of war. In 1940 Munro took on additional responsibilities as Chief Medical Officer to the Ministry of Supply and helped to organize and integrate an industrial medical service for the Royal Ordnance Factories. His scorn for paper work and a strong preference for making personal contacts won him many friends and admirers among the temporary civil servants. By 1943 he had retired from both these posts, but remained a member of the I.H.R.B. and a medical adviser to the Ministry.

For seven years he was a member of the General Advisory Board of this journal. As one of the first honorary members of the Association of Industrial Medical Officers he did much by his personality, warmth and culture to join together in friendship a small group of men and women pioneering in industrial medical practice. At one of the earliest meetings of this Association he reminded us that problems of industrial health were as old as antiquity by quoting from Ecclesiasticus :

" The smith also sitting by the anvil and considering the iron work —the vapour of the fire wasteth his flesh, and he fighteth with the heat of the furnace ".

Munro was willing to take on any burden of administration and it never seemed to worry him, but he always found time to live a full and happy life. Of the several honours he received none gave him greater pleasure than his election as Rector of St. Andrews University in 1938. To return to his old university which he had entered more than 40 years previously was the hey-day of his life.

RICHARD SCHILLING.

PROFESSOR MILLAIS CULPIN

Professor Millais Culpin died on September 14, 1952, at the age of 78.

He entered the field of industrial medicine rather by accident than by design. He was the son of a doctor in general practice in Stoke Newington, and was educated at the Grocers' Company School where, in addition to scholastic success, he acquired a life-long interest in entomology. For health reasons his father gave up his practice in London to set up in Brisbane. Millais tried his hand at various ways of earning a living, including an ineffective attempt at gold-mining, and eventually settled as a teacher in Cape York Peninsula for four happy years. He returned to London and qualified in 1902; he then went back to Australia, afterwards setting up in practice in Shanghai.

He married, and in 1913 returned to England in the hope of having a practice in the south of England, but the 1914–18 war broke out and instead he served in France in the R.A.M.C. His experiences as a surgeon turned his attention to the problem of psychoneurosis, and as soon as possible he returned to England to study "shell-shock". He was appointed lecturer on psychoneurosis at the London Hospital and settled down as a psychotherapist.

When two investigators of the Industrial Health Research Board produced experimental evidence that telegraphists' cramp was not primarily an organic muscular disease Dr. Culpin was appointed to study the condition and was able to show that it conformed to the group of disabilities known as psychoneuroses. This brought him into the field of industrial medicine and his appointment as professor at the London School of Hygiene and Tropical Medicine gave him further opportunities. After the investigation into cramp he studied the problem of miners' nystagmus, the loss of time in industry due to preventable sickness, the incidence of psychoneurotic disabilities, and the environmental conditions associated with their development.

He retired from research work in 1939 but continued some clinical work until his death. MAY SMITH.

THE OCTOBER (1952) ISSUE

The October (1952) issue contains the following papers :—

Blood Changes in Industrial Disease. By Ronald E. Lane.

The Carcinogenic Action of 4-Aminodiphenyl and 3 : 2′-Dimethyl-4-Aminodiphenyl. By A. L. Walpole, M. H. C. Williams, and D. C. Roberts.

Sickness Absence Recording in Industry. By J. P. W. Hughes.

Some Effects of Paid Sick Leave on Sickness Absence. By R. A. Denerley.

An Analysis of Absence under a Scheme of Paid Sick Leave. By R. B. Buzzard and W. J. Shaw.

The Role of Staphylococcal Infection in Beat Disorders of Miners. By J. B. Atkins and J. Marks.

Studies on Cotton Dust in Relation to Byssinosis. Part III : Comparison of Cotton Dust and House Dust by Chemical and Skin Tests. By H. R. Clayton, G. Furness, D. S. Jackson, and H. B. Maitland.

Airborne Bacteria in Cotton Mills. I. Survey of Counts of Viable Bacteria. By D. G. Drummond and Mary Hamlin. II. Determination of Types of Viable Bacteria. By Mary Hamlin.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 12s. 6d.

BOOK REVIEWS

The Scientific Study of Personality. By H. J. Eysenck. (Pp. 320 including index ; illustrated. 30*s*.) London : Routledge & Kegan Paul. 1952.

This book is a coordinating report of experimental studies of personality carried out since the publication of the author's earlier book *Dimensions of Personality*. The experimental work reported has been carried out by a number of investigators working under Dr. Eysenck's coordinating direction. It is important to ask, " For whom is this new volume intended ?" The phraseology of factor analysis forms a major part of the technical language in which the book is written. In spite of the popular exposition of factor analysis in one of the earlier chapters, it is doubtful whether the reader who is not statistically sophisticated will be able to follow the main arguments. He will thus be in the position of having to accept or reject the various conclusions from a dogmatic point of view rather than a scientific one. On the other hand, most critical, statistically sophisticated readers will require much fuller information than is usually presented here.

In spite of these criticisms the book is both interesting and stimulating to the academic psychologist. It raises a number of fundamental points concerning the scientific method in psychology, but the answers which the author gives will by no means be universally acceptable. As to the clinical psychologist, from a practical point of view, it is doubtful whether Dr. Eysenck has anything to offer immediately. However, his investigations and speculations form a valuable contribution towards a more effective definition and measurement of the dimensions of personality. There remain many loose ends and many psychologists will not accept his general approach and technique of analysis without grave reservations.

Eysenck begins his book with a discussion of the scientific method in personality research. His approach is deliberately atomistic and he takes physics as his model of the scientific method in action. It is at least a debatable point whether the form of scientific method suitable for investigating the complexities and subleties of human behaviour should be identical with that which has proved so successful in the exact sciences. Although Eysenck supports his thesis by quotations from eminent scientists who are not psychologists, it would be easy to bring together equally forceful arguments against many of the points he makes. In fact, if the standards of scientific detachment which are demanded by him are to be met, then this task is a necessary one. In spite of some appearances to the contrary, Eysenck does present his case in a detached, scientific manner, remaining neutral where he considers the evidence for a particular conclusion is incomplete. His challenging statement that there is no definite evidence to show that psychotherapy produces a favourable effect falls in this category.

Eysenck then passes on to consider the dimensional approach to the study of personality, still drawing strongly on the analogy with physics. In this context he outlines briefly the method of factor analysis which forms a major tool in the investigations reported and in their presentation. He is careful to point out that no hypothesis can ever be proved. It can only be consistent with a set of observations, and its efficacy is to be judged by the way such an hypothesis enables us to predict future events. In an attempt to render factor analysis a more effective tool in a " hypothetico-deductive " system Eysenck has developed a procedure known as criterion analysis. (Those who are familiar with factor analysis will be aware of the difficulty of equating factors in different studies. Eysenck's criterion analysis is an attempt to minimize this difficulty.) The method is closely bound up with the series of inferences which are made concerning the statistical properties of a single continuum or dimension, for it is from deductions of this type that Eysenck has claimed to have isolated the three main independent personality dimensions of neuroticism, introversion-extraversion, and psychoticism. By means of sets of tests he also claims to be able to measure neuroticism almost as effectively as one may measure intelligence. The groups of tests developed for measuring the other two dimensions may be described as adequate although their effectiveness is not explicitly specified. It is perhaps important to point out that no single test is considered to be adequate to define and provide an effective measure along one of these dimensions. The whole technique depends on using a battery or group of tests.

Considerable space is devoted to reviewing the evidence for the neurotic dimension and elaborating its operational definition. Stated briefly, the evidence consists of deducing, within a variety of contexts, a number of independent factors in terms of which one may account for the statistical relations between a number of traits or directly measured behaviour characteristics. Using a dichotomous psychiatric classification into normal or neurotic it is possible to refine the information supplied by individual factor measurements, and to identify such refined measurements as belonging to this factor of neuroticism. Many types of information may be " fed into " such an investigation and it is impossible to list all of these in a brief review. However, amongst the more effective sources of information are the following, each of which is discussed in some detail : ratings of personality traits ; questionnaires ; inventories of annoyances, interests, and worries ; food aversions ; manual dexterity test scores ; measures of

"level of aspiration"; dark adaptation; Rorschach scores; body build; and measures of "autonomic imbalance". A number of studies by Eysenck and his co-workers are reviewed, each of these lending support to the idea of a scientifically useful dimension of variation implied in the term neuroticism.

Passing on to discuss the relative effects of heredity and environment on neuroticism, Eysenck makes a short critical review of the use of fraternal and identical twins in this context. Although many of his criticisms may be correct, Eysenck's approach leads him to a more effective differentiation between fraternal and identical twins and this is followed by a report of a factorial study of the various dimensions of personality as shown in fraternal and identical twins together with a control group of neurotic children. The group of fraternal twins shows a higher neurotic score on the personality inventory than the identical twins and the latter also appear more inclined to lie. In general, the identical twin group appears to show a wider range of variation in mental stability than the fraternal group (as implied by the separate test scores and by the inferred factor measurements of neuroticism). Providing certain assumptions are made, it is further claimed that about 81% of the variations of neuroticism may be regarded as an inherited characteristic. This is an important conclusion for it is directly opposed to an earlier suggestion by Newman, Freeman, and Holtzinger (1937) that identical twins are not usually more alike than fraternal twins in personality characteristics. Eysenck concludes this chapter with two more "attacks". The first deals with the current fashion to over-emphasize the effects of environment. The second returns to the question of methodology by pointing out that correlation and causation must not be confused with one another and that in testing a theory one should endeavour to make deductions preferably in such a form as to decide conclusively between alternative hypotheses.

The next chapter is concerned with the psychotic dimension. Eysenck brings our knowledge of Kretschmer's position up to date, reviewing his recent contributions in this field. By giving a somewhat different group of tests to a population consisting of 100 normals, 50 manic-depressives, and 50 schizophrenics and then applying the same technique of analysis as those used previously to establish the dimension of neuroticism, the following conclusions were reached: (1) The psychotic states form a continuum with normal mental states. (2) Schizothymia-cyclothymia, put forward by Kretschmer, cannot be regarded as a separate dimension. This leads on to the development of an interesting threefold classification of mental disorders which can be illustrated by taking the average scores for the three groups either on two selected tests or on two hypothetical "tests" which "maximize" the discrimination between the groups. In this, as in the dimension of neuroticism, even if one does not accept this form of "dimensional analysis", the performance on these various tests, which significantly differentiate between the main classes of mental disorder, might serve as valuable aids to teaching some of the main objective symptoms.

Eysenck also discusses at some length the applications of dimensional analysis, drawing on a number of field studies by his colleagues. These studies are concerned with the following areas of investigation: (1) the direction of changes consequent upon pre-frontal leucotomy; (2) the employability of mental defectives; (3) work adjustment of unskilled workers; (4) selection of students and nurses; (5) sense of humour and popularity in teachers. Each of these studies warrants examination in considerably more detail than the information actually presented allows. It does not seem desirable to pick out individual conclusions from each study for presentation here.

The book concludes with a brief essay on the organization of personality, setting out, once more, Eysenck's predilection for atomism. Eysenck then returns to consider the question of personality organization. "Using our experimentally demonstrated three factors of neuroticism, psychoticism, and extraversion-introversion as three axes of a coordinate system, we can now locate a given patient in terms of his exact position within this system." In terms of this system to ask the question, "Is this person psychotic or neurotic?" is as sensible as it would be to ask, "Is this patient intelligent or tall?". Many independent dimensions of variation are necessary effectively to describe a person, and no claim is made that the present three dimensions are the only ones into which personality can be analyzed.

Eysenck ends with a discussion of some of the logical and factual difficulties in the way of rendering objective and scientific the sort of studies he has outlined. These include, above all, the difficulty of reproducing within defined limits any experimental situation. (It is this which, in the reviewer's opinion, is the main difference between the so-called exact sciences and the biological sciences, including psychology. It is a difference which demands that the scientific method must be considered in relation to a particular context.) Eysenck has also come to realize the "even slight changes in the test may produce profound changes in the results". Although conditions may be standardized, the psychological condition of the subject is less under experimental control. Nevertheless, if the evidence is accepted at its face value, the objective procedures put forward can lead to a surprising degree of precision in certain of these dimensions. The detailed analysis of the individual tests in relation to the performance of the individuals who carry them out is a task for the future. However, Eysenck believes that this task should go hand in hand with the work of establishing the main dimensions and refining the methods of measuring variation along these dimensions. So far, it is the second problem which has preoccupied Dr. Eysenck in this volume.

ROLAND HARPER

Mule Spinners' Cancer. Second Interim Report of the Joint Advisory Committee of the Cotton Industry. (6*d*. net.) Published by H.M. Stationery Office.

Mule spinners' cancer is still a problem in the spinning area of Lancashire. Although the number of mule spinners has decreased from 48,000 in 1926 to 22,000

at the present time, the number of notified cases is still more than 20 each year. To a certain extent ring spinning is replacing mule spinning, but it is the opinion of many authorities in the trade that the mule will never be superseded completely by the ring. The problem is therefore going to remain for some considerable time.

The first interim report of the Joint Advisory Committee was published in 1945. That report recommended, among other things, that oils used for the lubrication of mule spindles should conform to a specification commonly called the "Twort" specification, which was related to the specific refractivity of spindle oils, until such time as non-carcinogenic oils became available.

The present report discusses the application of technical white oils to mule spindle lubrication. These oils, which are water-white mineral oils closely related to medicinal paraffin, have been drastically refined with sulphuric acid so that all the unsaturated polycyclic hydrocarbons among which the carcinogens occur have been removed. In addition tests carried out by the Shirley Institute at the request of the Joint Advisory Committee have shown that they are just as efficient lubricants as the spindle oils normally used, and a specification for these oils has been set out based on colour and viscosity. The Committee says that although the specification may appear to some to be too simple to be effective, it is the most conclusive test of drastic refining which they have been able to accept. It is, for example, so sensitive in the range proposed that the addition of 0·5% of an ordinary spindle oil to one of these oils would bring it outside the specification. This is an improvement on the Twort specification which could be satisfied by mixing two different oils, neither of which conformed to the specification.

The Joint Standing Committee considered that the practice of blending mineral oils with fatty oils with the object of improving the lubricity of the former was not necessary, and they recommended that oils used for mule spindle lubrication should conform with the specification given above. The reason for this recommendation is that a blended oil is not capable of being tested by the method proposed. They also endorsed the recommendations in the 1945 report; first that there should be periodic medical examinations of all persons engaged in mule spinning, and second that suitable devices to prevent the splashing of oils from mule spindles should be provided.

The committee is aware that the Medical Research Council and the Institute of Petroleum are conducting a large scale investigation into the question of cancer and oil, but feel justified in making this interim recommendation until more information is available.

R. MURRAY

Rosenau. Preventive Medicine and Hygiene. 7th edition, edited by Kenneth F. Maxcy. (Pp. XV+ 1,462; illustrated. £5 5*s*.) New York: Appleton-Century-Crofts, Inc. 1951.

The last edition of Rosenau appeared in 1935. A new edition of the greatest textbook of preventive medicine is an important event especially when the new editor is so distinguished a man as the Professor of Epidemiology at Johns Hopkins School of Hygiene. Professor Maxcy has worked with a first-rate group of collaborators and the resulting text has the distinction and the scientific qualities which one would expect from its editor and his colleagues. The book can indeed be regarded as a statement of the teaching of the Johns Hopkins School.

Most of the text has been rewritten and recast in this edition; nevertheless the broad statement which the book conveys is very much within Rosenau's original frame of reference. The editor has probably paid a price for maintaining this original framework. Rosenau's first edition in 1913 had a more revolutionary approach to the subject for its day and age than this edition has for today. In his foreword written in 1913 Rosenau remarked that "preventive medicine has become a basic factor in sociology". Yet the latest edition deals slenderly with topics of medical sociology and the implementation of policies outside the fields of infectious disease and environmental control. Only a sixth of the text is devoted to personal health services and public health organization, with practically nothing at all on medical care. Some of the landmarks of the original Rosenau are missing, and one reader at least regrets the disappearance of Rosenau's well tried teaching expedient of the sanitary survey.

It is, however, churlish to criticize the book for not being something which its editor never intended it to be. The last sections of the book are those concerned with the epidemiology and prevention of infectious diseases. We owe a debt of gratitude to Professor Maxcy for providing such a complete treatise on the epidemiology of the school of Wade Hampton Frost. The breadth of discussion and the scientific balance of the section on the communicable diseases makes it invidious to pick out any one chapter for special comment. The statement on epidemiological methodology is a classic of its kind and well supported by Densen's chapters on statistical methods. The section on food sanitation and the sanitary control of water supplies, sewage and refuse disposal are strong outlines of the policy which follows from the epidemiological teaching.

The original edition of Rosenau had 24 pages on industrial hygiene and diseases of occupation. The present edition has a section of over 100 pages with chapters on occupational diseases, the general health of the working population, work and fatigue, and policies for the promotion of industrial medicine and hygiene. This section is contributed by Dr. Anna Baetjer who is also responsible for chapters on temperature, radiation (including atomic radiation), the effects of high and low barometric pressures, noise, atmospheric pollution, and resuscitation. Dr. Baetjer gives a lucid review of the mass of contemporary American research in these fields.

The book is well produced and illustrated, meticulously indexed, and carefully referenced. Everyone who takes preventive medicine seriously should have it. But it is very expensive.

J. H. F. BROTHERSTON

Applied Statistics. A journal of the Royal Statistical Society. (Single copy 10*s.*; 25*s.* per year.) Edinburgh: Oliver and Boyd. 1952.

This is a new journal designed to meet "the needs of all workers concerned with statistics" and devoted to the "practical statistical problems that arise in so many fields of human activity". Industrialists, scientists, economists, doctors, and many other persons interested in various and varied subjects have for a long time been aware of the growing importance of applications of statistics and statistical methods in their own particular fields, and there has been an increasing demand for a journal to meet the needs not only of professional statisticians but also of anyone who "must handle and understand statistics as part of their tasks".

The first two numbers of this journal have now appeared and include articles on a wide range of subjects. Although there are no specifically medical topics in these issues, it is planned to include some in later numbers and medical readers should find several of the present contributions of interest. Among these, the articles by L. T. Wilkins on "Estimating the Social Class of Towns", P. R. Cox on "Estimating the Future Population", and H. J. Eysenck on the "Uses and Abuses of Factor Analysis" will probably be of most general interest. Many a worker who has been confused by the existence of *two* regression lines will welcome W. N. Jessop's contribution "One Line or Two" in the second number. Another feature is "Questions and Answers" where queries on any topic whatsoever are welcomed from readers and will be dealt with by experts. This is one means of bringing the reader's demands before the editorial committee.

One of the great barriers between experts and users in any field is the seeming inability of the former to express his ideas in a language understandable to the latter. The editor claims that his aim is to maintain a "sound literary quality" in the articles with "just the right amount of details and explanation" so as to produce something that is easy to read and understand. Mr. L. H. C. Tippett's claim is amply justified in the first two numbers. *Applied Statistics* is recommended to anyone who in his own field deals with any aspect of the collection and presentation of accurate data.

N. M. GOODMAN

BOOKS RECEIVED

(Review in a later issue is not precluded by notice here of books recently received.)

Pre-eminent in the Relief of Pain. A handbook of data, indications and technique for therapeutic infra-red irradiation with the Sollux-lamp. 3rd ed. (Pp. 32; 4 diagrams. 2*s.* 6*d.*) Slough: Hanovia Ltd. 1952.

Report on the Health of the Army, 1946–1948. Edited by The War Office. (Pp. 116; 32 tables. No price.) 1952.

An International Bibliography on Atomic Energy, Vol. 2. Scientific Aspects. Supplement No. 1. (8,231 items; 2 appendices. 25*s.*) New York: Atomic Energy Section, Department of Security Council Affairs, United Nations. 1952.

Muscle Relaxation as an Aid to Psychotherapy. Vol. 1. Physical Medicine Series. By Gerald Garmany. (Pp. 65. 5*s.* 6*d.*) London: The Actinic Press. 1952.

Biological Hazards of Atomic Energy. Edited by A. Haddow. (Pp. 235; illustrated. 35*s.*) Oxford University Press. (London: Geoffrey Cumberlege.) 1952.

Expert Committee on Public Health Administrations. 1st Report. (Pp. 41. 2*s.* 3*d.*) Geneva: World Health Organization. London: H.M. Stationery Office. 1952.

Correction

Dr. Hughes regrets that in his paper in the October issue (**9**, 264) on "Sickness Absence Recording in Industry" he misquoted a statement from a paper by Spratling and Lloyd. The correct quotation should read: "The sickness absence of women is normally more than that of men, and that of married women more than that of unmarried women".

ABSTRACTS

(This section of the JOURNAL *is published in collaboration with the two abstracting Journals,* Abstracts of World Medicine, *and* Abstracts of World Surgery, Obstetrics, and Gynaecology, *published by the British Medical Association. The abstracts are divided into the following sections : toxicology ; industrial physiology ; industrial lung disease ; industrial skin diseases ; accidents and orthopaedic surgery ; industrial ophthalmology ; environment ; general. Not all sections will necessarily be represented in any one issue)*

INDUSTRIAL TOXICOLOGY

Blood Cholinesterase Levels in Workers Exposed to Organo-phosphorus Insecticides. BARNES, J. M., and DAVIES, D. R. (1951). *Brit. med. J.*, **2**, 816.

By the method described by Callaway, Davies, and Rutland (see below) the erythrocyte and plasma cholinesterase levels were determined in 130 specimens of blood from 80 men and women exposed to organophosphorus insecticides in field or factory. In 12 individuals abnormal variations were found which were probably attributable to absorption of the insecticide. Reduction of the erythrocyte cholinesterase content was found in 3 cases, and of that of the plasma in 5. Of 14 workers whose blood was analysed on more than 1 occasion, abnormally great individual variations were found in 8 ; of these, 4 had been removed from contact with the insecticides after the first examination and the level of the enzyme had risen in the interval, whereas in the other 4 contact continued during the interval and the fall in the enzyme level indicated some absorption. All departures from normal were slight, and no serious case of poisoning was encountered. *A. Schott.*

Blood Cholinesterase Levels and Range of Personal Variation in a Healthy Adult Population. CALLAWAY, S., DAVIES, D. R., and RUTLAND, J. P. (1951). *Brit. med. J.*, **2**, 812.

Certain compounds used as insecticides or proposed for chemical warfare may produce a significant reduction in the erythrocyte or plasma cholinesterase content before symptoms of systemic poisoning occur. Estimation of the level of these enzymes may therefore yield important information regarding the absorption of such compounds and also during the recovery from intoxication. The present paper deals with the normal levels, as determined in 247 healthy adults—100 men aged 18 to 30 years from the armed Services, 81 civilian men aged 18 to 60 years, and 66 women aged 27 to 74 years. The method is described in detail, and the unit of enzyme activity used is defined. No statistically significant difference was found between the mean values for plasma enzyme activity in the 3 groups, but the mean value for erythrocyte enzyme content was significantly higher in the Service group. The limits of variation for plasma enzyme activity in the whole series were between 57% and 143% of the mean value and for erythrocyte enzyme activity between 78% and 122% of the mean in the Service group and between 68% and 131% in the civilian groups. There were no sex, age, or seasonal differences in either value.

The individual variations in level were investigated in 10 soldiers by examining blood samples on 8 separate occasions. From this it is concluded that where it is possible to make only a single estimation of blood cholinesterase levels in an individual exposed to such compounds, while it can be ascertained whether the level is above or below the lower limit of normal for the whole population (which is well above that at which symptoms of systemic poisoning are likely to occur), a level found to be within the normal range for the whole population may be well below the normal range for that subject, since individual variations are much smaller than those of the whole population. Successive estimations in the same subject will yield more information regarding the possible absorption of such toxic compounds.

A. Schott.

Vapor Toxicity of Trichloroethylene Determined by Experiments on Laboratory Animals. ADAMS, E. M., SPENCER, H. C., ROWE, V. K., MCCOLLISTER, D. D., and IRISH, D. D. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 469.

In this paper is described experimental work undertaken as part of a comparative study of the vapour toxicity of four chlorinated hydrocarbons.

In carefully controlled experiments rats, guinea-pigs, rabbits, and monkeys were subjected to a single exposure to trichlorethylene, or repeated 7-hour exposures on 5 days weekly for periods up to 6 months. In rats the effect of a single exposure was to depress the central nervous system only ; full anaesthesia was induced at 4,800 parts per million (p.p.m.), but not at 3,000 p.p.m. All deaths occurred during the exposure or very shortly afterwards. Survivors recovered rapidly and completely. With repeated exposures a concentration of 3,000 p.p.m. produced no histological changes in the body tissues, but after the first week there were signs of functional disturbance during the times of exposure—hyperexcitability, restlessness, salivation, marked scratch reflexes, all of which subsided completely when the rats had been removed from the vapour chamber and had been fed. Repeated exposure to 400 p.p.m. caused no adverse effects in a monkey, but in guinea-pigs and rabbits it caused a slight increase in liver weight ; 200 p.p.m. produced no adverse effects in rats and rabbits, but a slight retardation of growth in guinea-pigs ; 100 p.p.m. caused no adverse effects in any animals. These results

support the accepted figure of 200 p.p.m. for the maximum permissible atmospheric concentration in industry.

It is suggested that the chronic effects experienced by workers exposed to trichlorethylene—fatigue, headache, gastro-intestinal malaise, and anorexia—represent primarily functional disturbances of the nervous system, and that the autonomic nervous tissues may be involved.

Tables and graphs give the mortality figures, growth curves, average final body weights, and organ weights of the animals exposed. *M. A. Dobbin Crawford.*

Vapor Toxicity of Ethylene Dichloride Determined by Experiments on Laboratory Animals. SPENCER, H. C., ROWE, V. K., ADAMS, E. M., MCCOLLISTER, D. D., and IRISH, D. D. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 482.

In this paper is recorded another part (see above) of a comparative study of the vapour toxicity of four of the chlorinated hydrocarbons.

The effects of single exposures and of repeated 7-hourly exposures to ethylene dichloride vapour at various concentrations were tested by carefully controlled experiments upon animals. With single exposures in rats three toxic effects were observed : (1) depression of the central nervous system, causing " drunkenness " at 12,000 parts per million (p.p.m.) and deep anaesthesia at 22,000 p.p.m. ; (2) shock : at all concentrations many of the rats died quietly and rather suddenly a few hours after removal from the vapour chamber ; and (3) organic injury, chiefly renal, causing death within 2 to 7 days of exposure. Only at concentrations above 3,000 p.p.m. were the lungs damaged, showing congestion and oedema. The adrenal glands were congested, with multiple haemorrhages.

Rabbits exposed to ethylene dichloride vapour in a concentration of 400 p.p.m. for 7-hour periods daily for 5 days a week and continued up to 6 months showed no adverse effects. The same concentration produced severe intoxication in monkeys, rats, and guinea-pigs, with cloudy swelling and fatty degeneration of the liver and congestion with degeneration of the tubular epithelium of the kidneys. A concentration of 200 p.p.m. caused no adverse effects in these animals except for a slight retardation of growth in rats. Repeated exposure to 100 p.p.m. produced no adverse effects in any of the animals. The adequacy of the generally accepted figure of 100 d.p.m. as the maximum permissible concentration of this gas in industry is therefore confirmed.

Detailed results are shown in tables and graphs.

M. A. Dobbin Crawford.

The Chylomicron Count as an Indicator of Phosphorus Poisoning. A Study Utilizing Experimental Animals. FLEMING, R. B. L., and COLLINGS, G. H. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 567.

In experiments on rats receiving a fat-free diet the base chylomicron counts were not significantly affected by acute or chronic phosphorus poisoning. The normal rise in level of blood lipids after the taking of food, however, was both diminished and delayed. This effect was greatest during the first 2 to 2½ weeks of the administration, and thereafter a tolerance developed. This tolerance was lost within 10 days of the last phosphorus injection. Details of procedure and chylomicron counts are given. *M. A. Dobbin Crawford.*

Response of Rodents to Repeated Inhalation of Vapors of Tetraethyl Orthosilicate. POZZANI, U. C., and CARPENTER, C. P. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 465.

Tetryl Toxicity : a Summary of Ten Years' Experience. BERGMAN, B. B. (1952). *Arch. industr. Hyg. occup. Med.*, **5**, 10.

Preliminary Observations on Toxicity of Elemental Selenium. HALL, R. H., LASKIN, S., FRANK, P., MAYNARD, E. A., and HODGE, H. C. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 458.

INDUSTRIAL LUNG DISEASE

Coal Workers' Pneumoconiosis. Pathological and Etiological Considerations. HEPPLESTON, A. G. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 270.

In order to compare the general pathological features of pneumoconiosis as it occurs in coal-workers in other areas with those of the disease as it occurs in South Wales, the author studied material from the U.S.A. (50 coal-workers, 19 employed in anthracite mines and 27 employed in bituminous-coal mines), Scotland (8 cases from steam coal mines), England (2 cases), Germany, and Russia (1 case each). As controls, lung tissues from 15 individuals with classical silicosis (mainly sandblasters and pottery workers) and from 25 town dwellers without occupational exposure to dust were examined.

As in South Wales coal-workers' lungs 2 main types of pathological change were observed in the lungs of coal-workers examined : massive collagenous fibrosis, which was found in 14 of the cases, and simple pneumoconiosis characterized by " coal macules ", which were present in all cases. The massive fibrosis was histologically similar to that found in Welsh cases, with coarse, irregular, hyaline, collagenous fibrosis, lymphocytic infiltration, endarteritis, and colliquative necrosis causing cavitation. Some cavities had a lining suggestive of chronic tuberculosis, and the author suggests that cavitation may be of two kinds, infective and ischaemic. In all the massive lesions there was an eosinophilic necrosis suggestive of tuberculosis, especially in the neighbourhood of the tuberculous granulation tissue which was found in some cases.

The macular lesions are described at greater length, and 4 stages of development are distinguished : (1) An early stage of dust collection around the divisions of the respiratory bronchioles in the interstitial tissue and extending into the surrounding alveoli, with a delicate network of reticulin. (2) Formative lesions develop, similar to the early lesions but extending more widely into the surrounding alveoli, and there is early trans-

formation of the reticulin into fine collagen. (3) Retrogressive lesions are found which are shrunken and compact, with bundles of fine collagenous fibres. These lesions have a stellate outline and there is emphysema of the surrounding and enclosed alveoli, which have attenuated walls and altered elastic fibres. (4) The progressive extension of the focal lesions leads to confluent lesions, so that the focal origin is largely obscured. In such cases there is extension of dust and fibrosis subpleurally, in the septa, and also along the broncho-arterial tree. The essentially focal nature of the lesion of the coal macule is stressed. Since there is no histological evidence of infection in the coal macules these must be attributed to the action of the dust alone. The massive lesions bear no resemblance to the macules and cannot therefore be due to their coalescence by collapse, so that they must be due to some factor other than the dust. The obvious factor is tuberculous infection. Of massive lesions in South Wales, 30% prove positive on culture for the tubercle bacillus, and the histology of the remainder is so similar that it may reasonably be supposed that in these cases the tubercle bacilli have been overcome, leaving a healed lesion ; moreover, the site at which massive fibrosis occurs is also the site of predilection for tuberculosis. However, it remains possible that other infections may be involved. The vascular changes are considered to be secondary to the fibrosis. It is pointed out that the large lesions are often surrounded by larger, hard nodules which have the same histology as the massive fibrosis and are probably also of infective origin. The distinction between this type of nodule and the coal macule has not been clearly made by previous workers.

The author then discusses whether any particular fraction of the dust is responsible for the macular lesion. In the past the silica fraction of the dust has been generally incriminated, even though it forms a very small proportion of the total dust, but if this were so the histology of the lesions should bear some morphological resemblance to that of silicotic nodules. The obvious differences from silicotic nodules are stressed : in particular, the disproportion between the amount of dust and the amount of fibrosis and the entirely different arrangement of the fibrosis. It is concluded that the two lesions have little in common, and it is pointed out that whereas in animals silica produces definite nodulation, coal dust produces no material fibrosis. The author therefore concludes that the silica is not responsible and suggests that the coal is not just a diluent, but is the active cause of the lesion, the lung being simply overloaded so that it can only respond by developing sufficient fibrosis to immobilize the dust. It is further pointed out that inhalation of rock dust by coal miners cannot be incriminated, since coal-trimmers exposed only to commercial coal dust in the holds of ships develop the same lesions. It is also stated that town-dwellers may have similar early lesions. The development of collagen in the retrogressive lesions cannot be taken as evidence of the action of silica, for a similar change may occur in other tissues (as in old uterine fibroids). Figures for the prevalence of pneumoconiosis in hard-coal workers in the U.S.A. are shown to depend more on total dust exposure than on the free silica content of the dust. Chemical analyses of lungs are unlikely to throw much light on this question because of the very poor association between silica content and severity of silicosis even in workers exposed to a pure silica risk. The focal emphysema is attributed to the force of inspiration acting on a focus of consolidation and causing mechanical stress in the surrounding lung. It is considered to be the cause of disability in simple pneumoconiosis. The final conclusion is that the word " anthracosilicosis " should be dropped and the words " coal-workers pneumoconiosis " substituted. *C. M. Fletcher.*

A Statistical Study of Pneumoconiosis in the Cement Industry. PARMEGGIANI, L. (1951). *Rass. Med. industr.*, **20**, 400.

***X*-ray Diffraction Study of Sputum in Silicosis.** MEYER, F., and SOLOMON, S. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 443.

The presence of silica was shown in the sputa of persons with silicosis by *x*-ray diffraction analysis. Positive *x*-ray diffraction identification of silica was obtained in the sputa of all 4 persons with severe silicosis investigated. No evidence of silica was found in the sputa of 10 control patients. While the presence of silica has been previously demonstrated by *x*-ray diffraction in lung tissue obtained at autopsy, the present study appears to be the first report on the successful application of this method to sputum obtained during life.

The method as used in this study was not quantitative. Considerable work will be required to determine whether *x*-ray diffraction of sputum has a place in the clinical diagnosis and investigation of silicosis.—(Authors' summary.)

Rönnskär Disease. (" Rönnskärssjukan ") LUNDGREN, K. D., RICHTNÉR, N. G., and SJÖSTRAND, T. (1951). *Nord. Med.*, **46**, 1556.

Since the ore-smelting works at Rönnskär, Sweden, were opened in 1929 there have been complaints of lassitude and shortness of breath on exertion from the men working there. In 1945 the Swedish State Hygiene Institute initiated a thorough investigation into the problem, the findings of which are now presented. This involved the medical examination of some 1,500 workmen employed in the plant and 500 control subjects, together with technical inquiries. The prevalence of a chronic rhino-pharyngo-tracheo-bronchitis with atrophic and hyperplastic changes in the respiratory mucosa was confirmed ; thick mucus is secreted and there may be emphysema. Rönnskär ore has a high concentration of arsenic, and it was possible to associate the occurrence of the condition among the employees at the works with the concentration of arsenic trioxide and sulphur dioxide, both of which are liberated with the fumes during the roasting and smelting processes. *W. G. Harding.*

Effect of Aluminium Dust on Susceptibility to Lobar Pneumonia—Animal Experiments. VINTINNER, F. J. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 217.

The experiments reported here are similar to those described above, except that pure metallic aluminium dust was used in high concentrations. The results were also similar to those in the coal dust experiment, in that there was a lower mortality and infection rate in the dust-exposed animals in the mucin experiments but no appreciable difference in the broth experiments. Indeed, in the latter there was a slightly higher mortality in the rats exposed to dust than in the controls, when the exposures were continued over a long period.

C. M. Fletcher.

ENVIRONMENT

Lobar Deposition and Retention of Inhaled Insoluble Particulates. STOKINGER, H. E., STEADMAN, L. T., WILSON, H. B., SYLVESTER, G. E., DZIUBA, S., and LABELLE, C. W. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 346.

The authors were unable to find in the literature any quantitative information on the retention of dust in the lungs after appreciable lengths of time, although a number of studies have been made on its deposition in various parts of the respiratory tract. They therefore carried out an investigation of the retention of particles of uranium oxide in the lungs of rats.

By spraying aqueous suspensions of sized particles 2 types of cloud were produced, 1 consisting of particles of U_3O_8 of a mass median diameter (M.M.D.) of 2·6μ, and the other of UO_2 of M.M.D. 0·45μ. [It is important to point out, although the authors do not do so, that these 2 oxides have densities of 10·9 and 7·3 respectively, so that the equivalent size of particles of unit density having the same terminal velocity (and therefore penetrating power) would be 7μ and 1·5μ respectively.] Rats were exposed to these clouds for periods varying from 6 to 54 hours, and killed after intervals ranging from 20 hours to 8 months. The amounts of dust retained in the whole left lung and in the various lobes of the right lung were estimated by a fluorophotometric method, and the following results were obtained: (1) After 6 hours' exposure to dust of M.M.D. 0·45μ, about 10 times as much was retained as after exposure to dust of M.M.D. 2·6μ for the same time and the same concentration, as measured with a gravimetric filter-paper sampler. (2) After 54 hours, exposure, 150 to 175% more dust was deposited in the right upper lobe of all rats, irrespective of particle size, than in other parts of the lung. (3) On comparing the dust content after 54 hours' with that after 6 hours' exposure, it appeared that dust was removed from this lobe about twice as fast as from all other lobes except the right median, from which no dust appeared to be removed at all. (4) Coarse dust appeared to be removed from the lungs more rapidly than fine, over periods of several months.

(The above observations were made on groups of 10 rats in each category, and the differences found were statistically significant.)

From the size distribution of particles in the 2 clouds, as studied by means of the cascade impactor, and from the observed difference in deposition of particles of different sizes, a "nasal filtration" cut-off point was calculated for the rat, "nasal filtration" being taken to include filtration by the whole upper respiratory tract, including the bronchi. This cut-off point was found to be 0·7μ which, the authors comment, compares with figures of 1·2μ found by Hatch and his co-workers. [Here again the authors ignore the effect of density; if this is allowed for, the cut-off point in the rat appears actually to be close to that in man.] Assuming a minute volume of 110 ml. per minute for the rat, the authors calculate the percentage retention for each size of particle and show that about 10% of the respirable fraction of both dusts was retained in the alveoli, although the percentage of the total was only 0·86 in the case of the coarse dust and 8·7 in the case of the fine. Anatomical studies of the rats' lungs suggested that the difference in deposition and retention of dust in different lobes could be explained on a physiological basis.

[This is an interesting and valuable piece of work but it is somewhat marred by the obscurity of its style, and by the failure to realize the fundamental importance of particle-density in lung retention studies.]

B. M. Wright.

Absorption and Excretion of Inhaled Fluorides. COLLINGS, G. H., FLEMING, R. B. L., and MAY, R. (1951). *Arch. industr. Hyg. occup. Med.*, **4**, 585.

This paper contains a brief description of an investigation into the absorption and excretion of inhaled fluorides under industrial conditions. Two human subjects (sex not stated) were exposed for 7 hours (being an 8-hour shift interrupted by four 15-minute intervals—three for decontamination and collection of urine, and one for lunch) to each of the following atmospheres: (1) an atmosphere containing hydrogen fluoride gas and silicon tetrafluoride gas at a mean concentration of 3·8 mg. per c. metre (maximum atmospheric concentration=2 mg. per c. metre); and (2) (several weeks later) one containing rock phosphate dust (3·5% fluorine) at a concentration of 5·6 mg. fluoride per c. metre, 95% of the dust particles being 5μ or less in diameter. The total urine was collected at 2-hour intervals during the exposure and for the next 2 days. For the supply of 2-hourly specimens a large fluid intake, producing a relative diuresis, was necessary.

In terms of total air-borne fluorine, the exposure to dust was 1½ times greater than the exposure to gas. Both subjects felt the irritant effect of the gas, but quickly became acclimatized. The dust caused no subjective symptoms. The normal daily fluorine excretion by the kidneys—1·2 mg. or less—was increased on the day of exposure to gas to 8·1 mg., and on the day of exposure to dust to 8·9 mg. Within 24 hours of the beginning of the exposure the urinary fluorine concentration was almost normal again; and it is suggested that the very small carry-over to the following day would have little cumulative effect.

M. A. Dobbin Crawford.

Brit. J. industr. Med., 1953, **10**, 69.

RESPIRATORS FOR PROTECTION AGAINST MERCURY VAPOUR*

BY

V. B. VOUK, Z. TOPOLNIK, and M. FUGAŠ

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Although the primary consideration in controlling a mercury vapour hazard should be engineering measures preventing the air from becoming contaminated, or eliminating the contaminant from the air, there are always many operations or working places where the application of these methods is impracticable or too costly ; for instance, charging furnaces or cleaning the main stack or condensers in a mercury smelting plant. In such kinds of work the engineering control must be supplemented or substituted by personal protective measures such as the use of air line respirators or respirators of the air-purifying type.

Before detailed consideration is given to the design and testing of respirators for mercury vapour it is necessary to discuss the adsorption, physical adsorption as well as chemisorption, of mercury vapour.

Physical Adsorption of Mercury Vapour on Porous Substances

It is well known that pressure and temperature have an effect on the amount of gas or vapour adsorbed on porous substances. Zelinsky and Rakusin (1926) investigated by a static method the adsorption equilibrium of mercury vapour on birchwood charcoal and found that it adsorbed considerable quantities of mercury. Coolidge (1927), however, who also used a static method, found that the adsorption of mercury vapour on activated coconut charcoal was negligible except at elevated temperatures. At 480° C. the maximum adsorption was 16·2 mg. per g. for a pressure of 730 mm. With decreasing pressure and temperature the amount adsorbed also decreased. At 100° C. and a pressure of 0·28 mm. the adsorbed quantity was only 2·7 mg. per g. At 20° C. he calculated (assuming the validity of Henry's law) that the maximum adsorption was 0·3 mg. per g. The calculated heat of adsorption (8,900 cal. per mole.), although lower than the heat of evaporation of mercury, was still greater than the heat of adsorption of many other gases. Thus the transfer of mercury atoms from the liquid phase to charcoal is endothermic and, therefore, favoured by high temperatures. On the other hand the transfer of mercury atoms from the gaseous phase to the adsorbent is exothermic and should proceed with ease at lower temperatures if no liquid mercury were present. It seems that the old model of capillary condensation, although not generally accepted, can help us to understand why this does not happen. The pressure driving a liquid into the capillaries of a porous substance is given by

$$P = \frac{2\gamma_L \cos \theta_A}{r}$$

where r is the radius of the (cylindrical) capillary, γ_L the surface tension of the liquid and θ_A the advancing contact angle (see e.g. Adam, 1948). For mercury γ_L is large (487 dynes/cm. at 15° C.) and therefore $\theta_A > 90°$. This means that the pressure must be applied to drive liquid mercury into the pores of the charcoal, and hence the capillary condensation cannot take place spontaneously.

The results obtained by Coolidge have been confirmed also by other authors. Table 1 summarizes the experimental results of the measurement of static and dynamic adsorption of mercury vapour on various adsorbents.

Chemisorbents for Mercury Vapour

The list of various chemisorbents for mercury vapour recommended for use in respirators is long. However from the study of the literature it appears that none of them is better than iodized charcoal. We found that silica gel impregnated with iodine and copper iodide, the chemisorbent proposed by

* A paper read at the tenth International Congress of Industrial Medicine, Lisbon, in September, 1951.

TABLE 1

COMPARISON OF VARIOUS DATA ON PHYSICAL ADSORPTION OF MERCURY VAPOUR

Adsorbent	Author	Adsorption (mg. per g.)	Temperature (0° C.)	Method
Birchwood charcoal	Zelinsky and Rakusin (1926)	46·9	20	Static
Activated coconut charcoal	Coolidge (1927)	0·3	20	Static
German gas-mask charcoal	Shiels (1929)	0·2	12–14	Static
Anticarbone A	Mora Agües (1932)	0·4	20	Dynamic
Animal charcoal "merck"	Alekseevskii (1933)	0·6	20	Static
Activated charcoal (Kahlbaum)	Alekseevskii (1933)	0·4	20	Static
American "charcoal"	Alekseevskii (1933)	0·4	20	Static
Activated Al_2O_3	Alekseevskii (1933)	Traces	20	Static
Chabazite*	Barrer and Woodhead (1948)	1·0	100	Static

*Chabazite is a hydrated silicate of aluminium, calcium, and potassium belonging to the zeolite group.

Yavorovskaya (1946), was not stable enough, for, when stored for three to four months, it gave off iodine. The preparation of manganese dioxide, another proposed chemisorbent of good qualities, is rather complicated. Iodized charcoal, on the other hand, has all the advantages of simple preparation, stability, and good protective power, and it was therefore decided to use it in further experiments.

The first proposal for using iodized charcoal as a chemisorbent for mercury vapour came from Stock (1931, 1934). Various methods have been described for the preparation of iodized charcoal. Most of them consist in the treatment of active charcoal with a solution of iodine in various solvents such as ethanol (DEGEA, 1933), benzene, carbon disulphide, chloroform, or an aqueous solution of potassium iodide. The adsorptive power of iodized charcoal depends on the method of preparation. It increases with the kind of solvent used in the following order: ethanol, benzene, carbon disulphide, aqueous solution of potassium iodide, chloroform (Pyankov, 1936). The difference in adsorptive power resulting from the use of different solvents for iodine is more pronounced the greater the concentration of mercury vapour reacting with the chemisorbent. The concentration of iodine should amount to approximately 5% by weight of charcoal (Pütter and Hirsch, 1934). If the iodine concentration falls below this value the adsorptive power decreases rapidly. Higher concentrations of iodine are not suitable owing to the possibility of desorption.

The fact that iodized charcoal adsorbs chemically more than twice the expected amount of mercury vapour is remarkable (Pyankov, 1936). It is probably connected with the method by which the charcoal is activated. The substance used in its preparation, such as chlorine or zinc chloride, may react chemically with the mercury vapour.

For practical purposes dynamic adsorption of mercury vapour on iodized charcoal is important. The life time or resistance time (t_R) is defined as the time necessary for mercury vapour of a given concentration, carried by an air stream, to penetrate a layer of adsorbent. It depends on the thickness of the layer, the concentration of iodine on charcoal, the concentration of mercury vapour in the air stream, the linear velocity of the air stream, to which the time of contact of mercury atoms and iodine is inversely proportional, temperature, the grain size of the adsorbent (Yavorovskaya, 1946), and the previous treatment of the charcoal.

Pyankov (1937) found that the equation

$$t_R = t_0 + K\,(L - L_0)$$

holds for iodized charcoal. Here L is the thickness of the adsorbing layer, and t_0, K, and L_0 are constants. This is a special case of the well known Mecklenburg's (1925) relation.

The relation between the concentration of mercury vapour, the concentration of iodine on active charcoal, and the velocity of air may be represented by the empirical equation

$$t_R = \alpha \,.\, c_I/c_{Hg} \,.\, 1/w$$

where α is a numerical factor (Pyankov, 1937), c_I and c_{Hg} are the concentrations of iodine and mercury respectively and w is the velocity in cu.m. per minute, the cross-section area and thickness of the iodized charcoal layer being constant.

The effect of temperature within limits important for practical applications is negligible.

The efficiency of chemisorbents increases with decreasing grain size (Yavorovskaya, 1946).

When estimating the efficiency of a given activated charcoal as a filtering material it is important to consider the treatment that it has undergone, i.e. the method of initial activation. Grosskopf (1938) showed that various industrial filters, not specially designed for use against mercury vapours, offer some protection against this hazard. Thus, e.g., "dräger filter SM483" designed for use against ammonia and H_2S had a resistance time of 1,440 minutes when tested at 20° C. and at a concentration of mercury vapour of 14 mg./cu.m.

Owing to the great number of relevant variables it is difficult to compare the experimental results on the resistance time of iodized charcoal as obtained by various workers. As an example of

experimental data we quote the results of Pütter and Hirsch (1934) who obtained a resistance time of about 100 hours for a special "auer" filter filled with iodized carbon with 3% iodine, when the air velocity was 30 litres per minute and the mercury concentration approximately 8 mg. per cu.m.

A Respirator for Mercury Vapour

In an attempt to make the working environment in the Idria mines less dangerous to the miners' health, a respirator giving protection against mercury vapour was designed in the laboratories of the Institute of Industrial Hygiene in Zagreb.

The following requirements were set up for an efficient filtering device against mercury vapour:—(1) The filter should be impermeable to mercury vapour up to a concentration of 10 mg. per cu.m. of air with a resistance time of at least 250 hours. The concentration limit of 10 mg. per cu.m. of air was set on the basis of the air analyses in the Idria mines (Vouk, Fugaš, and Topolnik, 1950) where the maximum concentration of mercury vapour found in normal working places was 5·9 mg. per cu.m. Special operations in the smelting plant may present greater hazards; for example, the workers who clean the main chimney and the condensers may be exposed to concentrations of mercury vapour as high as 30–40 mg. per cu.m. But the design of a general purpose air filtering device cannot be based on these extreme conditions. (2) The resistance to breathing, on inhalation, should be less than 6–7 mm. water head at a continuous flow rate of 30 litres per minute (or 25 mm. at 85 litres per minute). (3) The filter should also offer some protection against mercury aerosols. (4) The protective power of the filter should not decrease if stored for long periods of time. (5) Refilling of the canister should be easily performed. (6) It should not interfere with workers' freedom of movement.

Preparation of Iodized Charcoal.—A gas-mask charcoal (grain size 1·5 mm.) was used for the preparation of iodized charcoal; its water extract gave with silver nitrate a strong reaction of chloride ion. The first method used for preparation consisted in treating active charcoal with a 2·5% alcoholic solution of iodine (Yavorovskaya, 1946) and subsequently drying it at 50° C. The method gave good results, but it took quite a long time to prepare. Therefore we tried another simple method*. Active charcoal was mixed with solid iodine and kept at 60° C. and at the same time well stirred until all the iodine was absorbed. The concentration of iodine was 5% by weight of charcoal. Iodized charcoal prepared in this way was found very satisfactory. It was very stable, did not give off its iodine even on prolonged storage, and had no smell.

Measurement of Resistance Time.—The apparatus for the measurement of resistance time is shown schematically in Fig. 1. A stream of compressed air enters the apparatus through the flow meter (H) and passes the gas-washing bottle (M) containing pure mercury. The washing bottle is equipped with a fritted glass plate (N). The bottle is immersed in the water bath (L) which enables the heating of mercury up to 100° C. The air saturated or nearly saturated with mercury vapour leaves the washing bottle through the air ejector (K) where it is mixed with the other part of fresh air coming through the flow meter (J). The mixing of the air streams is completed in the bottle (E). From the bottle (E) the air-mercury vapour mixture enters the filter (B). Samples for determination of the concentration of mercury vapour are taken at (D) and (C). Before going to the exhauster the air stream passes the dry gas meter (A) where the total quantity of air passing the filter (litres per minute) is measured once more. Owing to the large difference between the room temperature and the temperature of the water-bath (L), the air saturated with mercury vapour cools down quickly when entering the ejector, and a rapid condensation of mercury vapour takes place which enhances the formation of mercury aerosols. Thus we were in the position also to test the permeability of filters to aerosols with the same apparatus.

Determination of Mercury Concentration in the Air Stream.—The analysis of air samples taken at (D) and (C) was performed by means of a Beckman spectrophotometer, which was specially adapted for this purpose. The ordinary light source of the Beckman instrument was replaced by a low pressure mercury vapour lamp having a maximum radiation output at 2536·5 A; the wavelength knob of the monochromator was also set at 2536·5 A. A 2310–100–89 cell was filled with the air to be analysed. For this purpose a special filling attachment was used. The optical density of the air sample was then measured. By means of a calibration curve it was possible to estimate with sufficient accuracy concentrations of mercury vapour as low as 0·05 mg. per cu.m. of air. Details of the application of the Beckman spectrophotometer for the determination of mercury vapour in air will be published elsewhere.

Results.—A layer of gas-mask charcoal (without iodine) 4 cm. thick was exposed to an air stream carrying 6·2 to 7·1 mg. per cu.m. of mercury vapour. In all experiments the velocity of the air stream was 200 ml. per sq. cm. per minute. This velocity was chosen because it corresponded to a rate of air passage of 30 litres per minute in the final shape of the respirator canister. The resistance time was found to be between 990 and 1,140 minutes.

Experiments carried out in order to find the effect of the concentration of iodine in the active charcoal gave the following results for a 2 cm. layer (Table 2).

In order to exclude the influence of mercury aerosols a fibrous filter was inserted in the air stream in front of the iodized charcoal layer. The iodized carbon layer alone was not able to hold up mercury aerosols. The testing was discontinued at 120 hours since Pütter and Hirsch (1934) have recorded 100 hours as the upper limit for 5% iodized charcoal.

* This method was suggested by Mr. Štucin from the Faculty of Medicine, Chemical Department, University of Ljubljana.

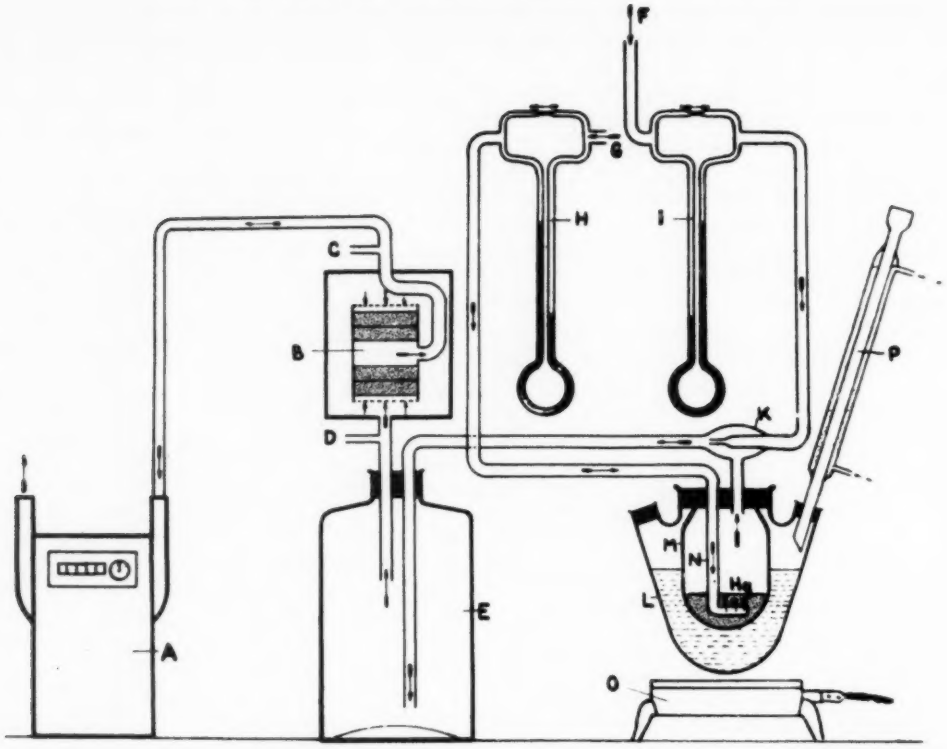

FIG. 1.—Apparatus for measuring the resistance time of filters: (A) dry gas meter, (B) mercury vapour filter, (C,D) outlets for sampling air-mercury vapour mixture, (E) mixing bottle, (F) dilution air inlet, (G) primary air inlet, (H,I) flow meters, (K) air ejector, (L) water bath, (M) gas-washing bottle, (N) glass tube, (O) electric heater, (P) reflux condenser.

TABLE 2

RESISTANCE TIME AS A FUNCTION OF CONCENTRATION OF IODINE

Percentage of Iodine in Iodized Carbon	Resistance Time (hours)	Mercury Concentration (mg. per cu.m.)
2·5	50	5 to 6·5
3·5	65	—
4·0	80	—
5·0	120	—

A series of experimental canisters was then constructed containing (*a*) a fibrous filter of the "wilson" or "M.S.A." dust respirator type, or a Yugoslav "vevče" paper filter, (*b*) a 2 cm. layer of iodized charcoal with 5% iodine, and (*c*) a 2 cm. layer of untreated gas-mask charcoal. The purpose of this last layer was to retain any iodine vapour that might be given off by the layer of iodized charcoal. A specimen of the results of measurement of the resistance time is given in Table 3. The resistance time thus proved to be between 285 and 295 hours. The mercury vapour load on the filter is visible from this table.

Types of Fibrous Filter.—The breathing resistance of experimental canisters was found to depend to a large extent on the quality of the fibrous filter. The resistance of the charcoal layers alone amounted to 2 mm. water head. The best results with regard to the breathing resistance were obtained with an experimental dust filter produced at the Institute for Cellulose and Paper in Vevče, Ljubljana (Slovenia). The resistance of the complete canister at 30 litres per minute was 5·5 mm. of water (16 mm. at 85 litres per minute). The canister equipped with an M.S.A. dust filter showed a resistance of 7·5 mm. of water at 30 litres per minute. There was no difference in resistance time when the "vevče" filter was used instead of the "wilson" filter. The total cross section of the filter was 150 sq. cm.

Field Testing

Although the laboratory experiments with filters had given satisfactory results with regard to their protective power against atmospheric mercury and their resistance to breathing, there remained various questions which could be answered only by field testing. Are the respirators comfortable? Do they interfere with the free movement of workers? What is the workers' attitude towards such personal protective devices? Are they willing to suffer some additional discomfort, which is inevitable, for the

TABLE 3

MEASUREMENT OF THE RESISTANCE TIME IN EXPERIMENTAL CANISTER NO. 10

Testing Time (hours)	Concentration of Hg in front of Filter (mg. per cu.m.)	Concentration of Hg behind Filter (mg. per cu.m.)	Testing Time (hours)	Concentration of Hg in front of Filter (mg. per cu.m.)	Concentration of Hg behind Filter (mg. per cu.m.)
1	8·4	0·00	166	7·8	0·00
6	8·2	0·00	173	6·8	0·00
13	7·8	0·00	178	8·0	0·00
19	7·7	0·00	184	7·7	0·00
25	5·9	0·00	191	6·5	0·00
31	8·0	0·00	Testing discontinued ; canister subjected to prolonged mechanical vibrations		
36	9·2	0·00			
41	8·4	0·00	196·5	7·3	0·00
46	8·0	0·00	200·5	7·8	0·00
52	7·9	0·00	207	7·9	0·00
60	8·2	0·00	213·5	7·1	0·00
67	7·9	0·00	219	5·5	0·00
73	7·0	0·00	225	7·8	0·00
77	7·8	0·00	230·5	7·7	0·00
83	5·5	0·00	237·5	7·8	0·00
88	5·2	0·00	247	7·5	0·00
93	7·7	0·00	254	7·1	0·00
Testing discontinued for 3 hours			263	6·8	0·00
94	6·8	0·00	267	10·4	0·00
99	7·3	0·00	274	10·3	0·00
105	7·9	0·00	279	10·1	0·00
112	7·8	0·00	285	10·4	0·00
118	7·3	0·00	295	9·5	0·096
124	7·7	0·00	298	10·1	0·095
130	8·2	0·00	303	10·3	0·030
136	7·7	0·00	311	10·7	0·14
143	7·7	0·00	317·5	11·2	0·10
149	7·9	0·00	327	9·4	0·14
154	8·1	0·00	333·5	9·4	0·15
160	7·9	0·00	340	7·4	0·27

Filling : fibrous filter " Vevče-P_2 "—2 cm. iodized carbon (5%)—2 cm. gas-mask charcoal. (Breathing resistance : 5 mm. water head at 30 litres per minute)

sake of preserving their health ? It is very important to obtain at least partial answers to these questions before the use of respirators can be recommended, since the efficiency of such preventive measures depends as much on the subjective factors, such as the care of workers in maintaining the respirators and their discipline in wearing them, as on objective factors, such as impermeability of the filter to the atmospheric contaminant and its breathing resistance. It is obvious that the efficiency of this protective measure will be much less if the workers are coerced to wear the respirators than if they ask for them.

Our preliminary field testing was conducted in the following way. Two working teams were organized in the mines of Idria. The first team consisted of four men wearing respirators (two miners and two members of the Institute of Industrial Hygiene) and one miner working without a respirator. The wearers of the respirators worked 10 days (six hours daily). The miner who was unprotected worked only five days, and was then replaced by another miner who also worked five days. The average concentration of mercury vapour at the working place was 1·2 mg./cu.m. (determined by means of a selenium sulphide detector).

The second team consisted of only two miners wearing respirators. The concentration of mercury vapour at their working place amounted to 2·0 mg./cu.m.

The members of both teams were daily examined by the mine's medical officer. The excretion of mercury in urine was followed only qualitatively using a method described by Pinter and Ružđić (1942)* for detecting mercury in urine.

These preliminary tests gave quite satisfactory results with regard to the protective power of the respirator, but suggested some minor changes in the design of the respirators. None of the wearers of the respirator in the first as well as in the second team showed any clinical symptoms of mercury poisoning to the end of the experiment which lasted 10 days. No mercury was found in the urine. The first miner, a member of the first team, who worked without the respirator started to excrete mercury in urine on the first day, and clinical symptoms of mercury poisoning (stomatitis, gingivitis, salivation combined with erethism, and tremor) developed in the course of five days to such an extent that he had to be replaced. The second miner, who took his place, proved more resistant to the influence of mercury vapour. He also worked five days six hours daily, but the excretion

* This method is based on catalytic decomposition of ferrocyanide-ions in the presence of mercuric-ion.

of mercury in urine did not start until the fourth day, and he showed no clinical symptoms of poisoning even on the fifth day when the experiment was discontinued.

Two miners, members of the first team, continued to work wearing respirators for a total of 20 days. They did not show any clinical signs of mercury poisoning or mercury exposure even after that length of time.

After the end of field experiments the six respirators were again subjected to laboratory tests. They were still absolutely impermeable to atmospheric mercury, but their resistance to breathing increased to more than 10 mm. of water head owing to the saturation of the cellulose filter with dust. Thus the filter became unusable though the iodized charcoal filling would have lasted much longer.

On the basis of these experiences in field tests the respirator was redesigned, the filling of the filter remaining the same. Besides some other minor changes the new design provided for ready cleaning and exchange of cellulose filters. The re-designed respirators were again subjected to field testing in the course of seven days (six hours daily). The selenium sulphide detector showed a concentration of 2·5 mg./cu.m. of mercury vapour (dithizone method gave 4–5 mg./cu.m.) at the working place where the respirators were tested. These experiments again confirmed that the protective power of the respirators was sufficient : none of the miners who wore them showed any clinical symptoms of mercury poisoning. At the end of the experiment the workers were questioned as to the feeling of discomfort caused by wearing respirators, and they unanimously agreed that the respirators were reasonably comfortable and did not appreciably interfere with their free movement. Our impression was that the workers could easily be persuaded to wear respirators at work. Obviously some feeling of discomfort could not be avoided owing to the long wearing period (five to six hours daily). There is no doubt that the respirators do not represent the final solution to the problem of mercury poisoning in the mines but that as a temporary measure they can be used owing to the lack of other measures of controlling this hazard.

FIG. 2.—Face piece.

On the other hand short-term operations, such as the yearly cleaning of Špirek condensation chambers, represent the type of work for which the respirator is appropriate. Two men employed in cleaning condensation chambers used respirators for six days (five hours daily). They showed no clinical symptoms of mercury poisoning nor any signs of exposure to mercury vapour although the concentration of atmospheric mercury ranged from 16·2 to 18·5 mg./cu.m. Because of the extremely high concentration of mercury vapour the thickness of the iodized charcoal layer was increased to 4 cm. and the iodine concentration in the charcoal to 10%.

We are aware that these preliminary field experiments do not furnish sufficient evidence to pass a definite judgment on the suitability of respirators,

FIG. 3.—Canister harness.

FIG. 4.—Side view.

but we believe that they justify any experiment on a larger scale.

The Final Form of the Respirator

The facepiece (Fig. 2) is similar to that of the M.S.A. " comfo " respirator. It is connected by a

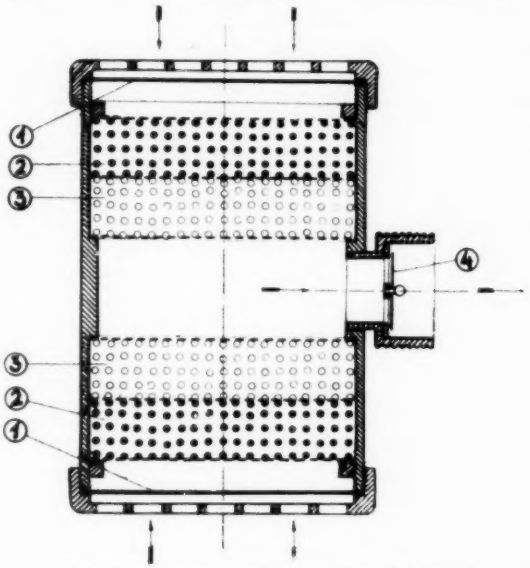

FIG. 5.—Filter in cross-section : (1) fibrous filter, (2) iodized charcoal layer, (3) gas-mask charcoal, (4) inhaling valve.

flexible corrugated rubber tube to the canister which is carried on the back. The arrangement of the harness can be seen in Figs. 3 and 4. The facepiece has two exhaling valves in order to reduce the exhaling resistance to the least possible value. The " star-like " valves are visible in Fig. 2.

The canister in cross section is shown in Fig. 5. It consists of two identical valves containing a fibrous filter, a layer (2 cm.) of iodized carbon and a layer (2 cm.) of gas-mask charcoal. The two air streams merge into one in the central tube connected to the corrugated rubber tubing. This design was adopted in order to achieve the minimum breathing resistance. Approximate dimensions of the canister are : diameter, 10 cm., length, 16 cm. The canister may be opened at both ends by unscrewing the perforated lids so that the fibrous filter and the filling may easily be exchanged. The canister weighs about 800 g. One filling consists of 300 g. of iodized and 300 g. of untreated gas-mask charcoal.

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THE ACTION OF FLINT OF VARIABLE SIZE INJECTED AT CONSTANT WEIGHT AND CONSTANT SURFACE INTO THE LUNGS OF RATS

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The importance of the size of the dust particles concerned in the production of silicosis has been widely appreciated, but the relationship between particle size and intensity of tissue reaction in man is complex. The size of the dust exerts a direct influence upon the number of particles suspended in the air to be inhaled, and on the penetrating power of the particles into the lung. Other factors, such as distribution, weight, flocculation, and aggregation, and variation in the composition of dust in air, depend much on the size of the particles. In the last few years the attention of many workers in this field has been drawn to investigating the range of sizes capable of entering the lung, and the relation of particle size of a particular dust to maximum pathogenicity.

This field has been ably discussed by Hatch and Hemeon (1948) who point out the need for further research to determine the relation between toxicity of quartz and particle size.

As it has been possible to produce definite silicosis in experimental animals within a reasonably short period with free silica dusts, different particle sizes of such dusts might be expected to produce appreciable differences in lung pathology within a convenient experimental time. Some experiments in this field have been carried out by Gardner and Cummins (1933) and Tebbens, Schultz, and Drinker (1945). Gardner and Cummins used intravenous injection into rabbits of quartz of diameter 1–3μ and 6–12μ, and also of aluminium oxide 1–3μ. They found that the fine quartz fraction produced hyaline fibrosis, mainly in the liver, whereas the coarse quartz only gave a foreign body type reaction. The aluminium oxide did not produce any reaction.

Tebbens and his colleagues also used intravenous injection into the ear veins of rabbits of suspensions of 400 mg. quartz of mean sizes 3·3, 1·7, 1·0, and 0·6μ diameter. These produced fibrosis in various organs, particularly the liver and spleen, and the smallest particles were much the most active. It was concluded that

> " Particles of 1 micron and under are the most active and dangerous, not only in their ability to remain suspended in the air, but even of greater importance is their activity once they gain entrance to the deeper recesses and to the body and tissue."

Hatch and Kindsvatter (1947) made dust inhalation experiments on guinea-pigs with quartz below 0·5μ diameter. The dusting period lasted from four to 20 weeks, and the authors calculated that up to 35 mg. per animal could have been retained in the alveolar tissue. Lung sections were illustrated showing fibrosis after 20 weeks, but no detailed pathological description was given. Attention was drawn to the rapidity of the lung changes, and it was claimed that 35 mg. per animal was " strikingly below the dosage commonly employed ".

From these studies it appears that silicosis can be experimentally produced either by inhalation or by injection of silica dusts of a wide range of particle size, the upper limit of which should be less than 10μ. About the lower limit little is known ; it is probably above 0·002μ (c.f. King, 1947 ; Dale and King, 1953) and may be above 0·2μ. To carry out further investigations on the relation of particle size to pathogenicity, and with dusts more accurately

sized than those previously employed, experiments were set up using flint in several fractions covering the range from below 0·5μ to 8μ equivalent diameter.

As we are attempting to develop animal techniques in silicosis research along quantitative lines, injection methods are necessary for such work. Only in this way is it possible to introduce a known dosage directly into the lung tissue. It is recognized that such methods are further removed from industrial conditions in man than are animal inhalation experiments. But a number of complications arising out of maintenance of a dust cloud, the access and/or retention of different amounts of dust in the lungs (see the variable amounts found in inhalation experiments by King, Wright, Ray, and Harrison, 1950), possibly different breathing rates of animals, lung retention characteristics, are all avoided. The experiments were therefore carried out by intratracheal injection. In a first series equal weights of pure flint of five different size doses were injected into the lungs of rats.

The pathogenicity of silica dust is probably a function of the total surface it exposes to the tissues. Two different mechanisms may be involved. Solubility is certainly proportional to the surface and if the fibrogenesis is related to "solubility" then a given dust will act in proportion to its surface. But, if it is not the dissolved silica but the surface itself that acts, perhaps as a catalyst promoting protein degeneration and fibrosis without actually being used up in the process, then surface also is the deciding factor.

Before these relations can be studied in detail it is desirable to get qualitative, and, if possible, quantitative information on the limiting upper and lower sizes that cause such fibrosis and on their different effects on lung tissue.

We, therefore, tested the effects of constant surface area, as well as constant amounts (by weight) in relation to the fineness of particle size. For this purpose the same flint dusts as used in the constant amount experiments were used for a series of tests employing variable amounts of dust to give a constant surface area in each case, with the same wide range of particle sizes.

DESCRIPTION OF SAMPLES

A very pure commercial sample of ground calcined flint was used. It contained by chemical analysis over 99% of silica. After size fractionations were carried out it was found that all fractions, including the finest sample (below 0·5μ), still contained, on an ignited basis, well over 99% of silica. There were five flint samples with the following nominal size limits: under 0·5μ, 0·5–1μ, 1–2μ, 2–4μ, 4–8μ. The size separations for the fractions up to 2μ were done by centrifuging, and for the larger fractions by settling in distilled water without using any dispersing agent. The finest fraction was isolated first, and 30 or more repeated centrifugations were required to remove the particles below 0·5μ equivalent diameter as completely as practicable. The residue was used to isolate the next coarser fraction, and so forth.

Details of the size distribution and chemical composition of the samples are given in Table 1. The nominal sizes of the samples given above refer to equivalent spherical diameters, whereas the measured sizes in Table 1 refer to projected diameters. Insofar as the particles are not spheres the projected diameters are larger. The size distribution of the fraction below 0·5μ was obtained using the electron microscope, and those of the larger fractions using the light microscope. The estimates of the surface areas were derived by calculation from the size counts.

All fractions were examined by *x*-ray diffraction technique. They showed a strong quartz pattern and a medium-strong cristobalite pattern. There was no evidence of any change in the cristobalite/quartz ratio for the different size fractions. The sample of flint of 2 to 4μ size was analysed by a quantitative *x*-ray diffraction method and found to contain approximately 50% of quartz and 35 to 45% of cristobalite. Fig. 1 shows the diffraction patterns of quartz, flint, and cristobalite.

PREPARATION OF THE DUSTS

Amounts of 2 g. of each size fraction were weighed into 100 ml. conical flasks, and well shaken with 60 ml. of sterile physiological saline. These flasks were sterilized by autoclaving (20 min. at 15 lb. pressure) on the day of injection. Thus 1·5 ml. of the dust suspension contained 50 mg. of the individual dust, and this amount was injected into each animal.

The same flint dust was used for the constant surface area experiments. It was calculated that 8 mg. of <0·5μ, 17·5 mg. of 0·5–1μ, 42·5 mg. of 1–2 μ, 100 mg. of 2–4 μ, and 199 mg. of 4–8μ dusts had an equivalent surface area (700 cm.^{2}). But as the amounts of the dusts in the last two sizes were too large for a single injection, it was decided to inject all the animals in divided doses, the first four sizes of the dust in two doses, and the last one in four doses, at weekly intervals. Accordingly two lots of 0·2 g., 0·437 g., 1·062 g., and 2·5 g. respectively from the <0·5μ, 0·5–1μ, 1–2μ, and 2–4μ dusts, and four lots of 2·488 g. of 4–5μ size, were weighed into screw-cap containers. On the day of the injections one bottle from each size was taken, and well shaken with 25 ml. of sterile physiological saline. The bottles were sterilized by autoclaving. Of the dust suspension,

TABLE 1

SIZE DISTRIBUTION AND ANALYSIS OF FLINT DUSTS

Size (μ)	4–8μ Per cent.		2–4μ Per cent.		1–2μ Per cent.		0·5–1μ Per cent.		<0·5μ Per cent.	
	By No.	By Mass	By No.	By Mass	By No.	By Mass	By No.	By Mass	By No.	By Mass
<0·16	—	—	—	—	—	—	—	—	31·5	2·8
0·16–0·23	—	—	—	—	—	—	2	0·1	29·5	6·6
0·23–0·32	—	—	—	—	—	—	9	0·9	20·4	11·3
0·32–0·45	13	0·005	6	0·01	—	—	29	8·1	9·3	12·9
0·45–0·64	8	0·01	3	0·02	—	—	40	31·5	7·1	31·2
0·64–0·9	10	0·03	4	0·05	—	—	17	39·0	1·8	21·7
0·9–1·3	11	0·1	7	0·22	3	0·4	2·9	18·6	0·4	13·5
1·3–1·8	12	0·3	10	0·9	35	10·9	0·1	1·8	—	—
1·8–2·6	12	0·7	24	6·5	47	42·1	—	—	—	—
2·6–3·6	6	1·2	24	18·4	13·4	33·0	—	—	—	—
3·6–5·1	4	2·2	17	36·7	1·4	9·7	—	—	—	—
5·1–7·2	9	14·3	4·4	26·9	0·2	3·9	—	—	—	—
7·2–10·2	10	45·0	0·6	10·3	—	—	—	—	—	—
10·2–14·4	5	36·1	—	—	—	—	—	—	—	—
Particles counted ..	280		271		365		332		495	
Estimated surface area (m^2/g.) ..	0·44		0·69		1·6		4·0		6·7	
SiO_2(%)	98·4		99·2		99·4		99·4		98·8	
Ignition loss (%) ..	0·3		1·8		0·1		0·9		2·2	
Silica "solubility" at "constant weight," i.e., 2% suspensions of the flint dusts (SiO_2 mg./100 ml.)	5·1		8·9		13·1		13·4		13·6	
Silica "solubility" at "constant area," i.e , 7000 $cm.^2$ per 100 ml. Ringer solution	4·1		4·2		4·6		2·1		4·1	
Approximate no. of particles in dose given (mg.) in "constant area" experiment ..	$0·5 \times 10^9$ (199 mg.)		2×10^9 (100 mg.)		10×10^9 (42·5 mg.)		63×10^9 (17·5 mg.)		135×10^9 (8 mg.)	

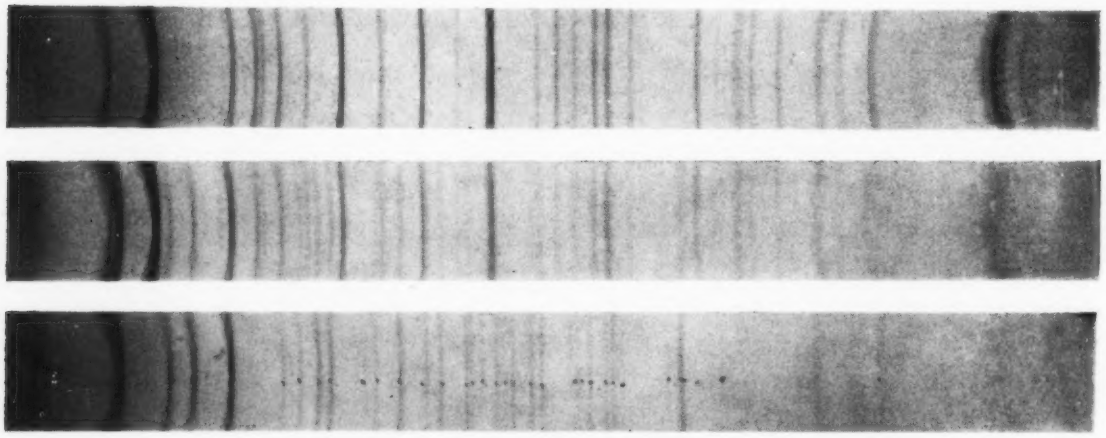


FIG. 1.—Diffraction patterns of quartz, flint, and cristobalite.

0·5 ml. corresponded to 4, 8·75, 21·25, 50, and 50 mg. of <0·5, 0·5–1, 1–2, 2–4, and 4–8μ dusts, respectively. To complete the full dose this amount from each dust was injected twice in the first four and four times in the last case.

When these samples were prepared the size distribution

of the fraction below 0·5μ could not be determined as the electron microscope of the Sheffield laboratory had not yet been installed. Subsequent checks showed that the specific surface of this fraction had been overestimated and the dosage given (8 mg.) actually corresponded to only 520 cm.^{2} per rat.

ANIMALS

Thirty male rats were used for each size of the dust. They were from the Medical Research Council black and white strain, and their average weight was 225 g.

EXPERIMENTAL PROCEDURE

In the constant-amount experiments the dust suspensions were injected into the lungs of the animals intratracheally following the technique of Kettle and Hilton (1938) modified by Belt and King (1945). The rats were anaesthetized lightly with ether, and the trachea was exposed by blunt dissection. The sterile dust suspension was well shaken, and 1·6 ml. (about 0·1 ml. usually remained in the syringe) was withdrawn through the rubber cap, using a 5 ml. syringe to which a short sharp needle (1 in. × 22 gauge) was fitted. To obtain good dispersion of the dust into the lung alveoli the suspension was kept agitated until the time of injection, and to prevent sedimentation within the syringe it was emptied quickly with a certain amount of force into the lungs. A small amount was occasionally regurgitated. The wound was closed by a single suture.

While this technique appeared suitable for constant amounts of dust, the following difficulties were foreseen in its use for injecting the animals for constant-surface-area experiments :—(1) It would probably be more difficult to operate at the same site several times at weekly intervals ; (2) the repeated operations might expose the animals to external infections, and thereby lead to a high mortality rate among them ; (3) occasional regurgitation of the suspension of the dust would make a great variation in the surface area of the injected amount.

To avoid these difficulties it was decided to modify the technique by abolishing the incision and injecting the dust suspension *via* the mouth through a long, blunt needle at the bifurcation of the trachea. The amount of fluid in which the dust was suspended was also kept as small as possible so that the risk of regurgitation would be minimized.

The rats were anaesthetized as before. The tongue was retracted with a small clip. An auroscope fitted with a medium-sized speculum was passed into the mouth as far as the oropharynx. After cleaning the throat of mucus with a swab the two vocal cords were seen running vertically. The cords were lightly touched with 2% " anethaine " solution to produce temporary local anaesthesia. A large, blunted needle (4 in. × 14 gauge) was passed between the cords, keeping the tip of the needle in touch with the anterior wall of the trachea so that it glided over the trachea rings while it was passed forwards, and imparted a vibrating sensation to the needle. When the end of the needle hit the corina it was withdrawn about 2 mm. The sterile dust suspension, kept agitated in a mechanical flask shaker, was withdrawn through the rubber washer, using a 1 ml. syringe to which a short, sharp needle (1½ in. × 20 gauge) was fitted, and 0·75 ml. was taken, since 0·25 ml. (on the average) remained in the syringe and the large needle, and a little air (about 0·2 ml.) was also drawn into the syringe. The syringe was quickly removed from the short needle, and attached to the large needle in the trachea. The suspension was injected quickly and forcibly. In this way, with the jet of the suspension hitting the corina, the dust runs into both the lungs in approximately equal amounts. The small amount of air in the syringe assists in the shaking to keep the dust in suspension, and also helps to eject the last of the dust suspension from the syringe and through the needle. The needle is kept in position for a second or two and then withdrawn quickly. Immediately after the injection a short period of apnoea of about two to three seconds was noticed, which was followed by a deep breath. No regurgitation of the suspension was seen.

PATHOLOGICAL TECHNIQUE

Routine necropsies were carried out on the rats which died and were killed. The lungs of the killed animals were gently distended by injecting about 10 ml. of 10% formol-saline through the trachea, which was exposed at the neck. Most of the air in the lungs was expressed by gentle pressure on the sides of the thorax before the injection was made. The trachea was tied off, the thoracic cavity opened, and the lungs, with the tied-off portion of the trachea, were removed and placed in the fixative. In the case of the dead ones, the lungs were first removed intact, examined, and then distended gently with the fixative to the normal size, as satisfactory replacement could not be obtained otherwise. After preliminary fixation for four days blocks were selected in the long axes of both the lungs at the level of the hilum to obtain maximum representative areas from each lung and to include the hilar lymph nodes. After complete fixation, the blocks were embedded and cut in paraffin at 5μ. Sets of four serial sections from each lung were taken. The first was stained with Gordon and Sweet's silver impregnation, the second with haematoxylin and eosin, the third was for microincineration, and the fourth was kept as spare and was used for Gram's stain in some cases to exclude infection.

DURATION OF EXPERIMENTS

Forty-one rats from the constant-amount series and five from the constant-surface series were lost by death and cannibalism. The rats were killed at monthly intervals up to a period of one year, and in the constant-surface series up to 500 days. Because of the large number of deaths in the constant-amount series it was difficult to maintain the killing intervals constant all through the experimental period. However, with long enough intervals between killings it was possible to extend the experiments up to one year (Table 2).

In the constant-surface-area series the animals survived better, and after three months two rats from each group were taken at every killing period, up to 500 days, when the experiment was terminated.

TABLE 2

ASSESSMENT OF FIBROSIS IN LUNGS OF RATS PRODUCED BY A CONSTANT AMOUNT (50 mg.) OF DIFFERENT PARTICLE SIZES OF FLINT DUST

Samples	4–8μ		2–4μ		1–2μ		0·5–1μ		<0·5μ	
Days of Survival	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis
1–30	D	(–)	D	(–)	D	(–)	D	0	D	(–)
	D	(–)	D	(–)	K	2	D	(–)	D+	2
	D	0	D	(–)	—	—	D	1	D	2
	D	0	D	0	—	—	D	(–)	D	3
	K+	1	D	0	—	—	K+	2	K	4
	—	—	K+	1 max.*	—	—	—	—	—	—
31–60	D	1	D	(–)	D	1	D	(–)	D	(–)
	D	1	D	(–)	D	1	D	3	D	(–)
	D	(–)	D	(–)	D	(–)	D	(–)	D	(–)
	D	1	D	(–)	D	(–)	D	(–)	K	4
	D	(–)	—	—	D	(–)	D	(–)	—	—
	D	1	—	—	D	(–)	D	(–)	—	—
	D	(–)	—	—	K	3 min.	D	(–)	—	—
61–90	D	(–)	K	1	D	2	K	2	D	(–)
	K	2 min.*	—	—	K	3 min.	—	—	D	(–)
	—	—	—	—	—	—	—	—	D	3
91–150	K+	1	K+	2	D	2	D	4	K	3
	—	—	—	—	D	2	D	4	D	4
	—	—	—	—	K+	3	D	4	D	(–)
	—	—	—	—	—	—	D	4	D	(–)
	—	—	—	—	—	—	D	(–)	D	3
	—	—	—	—	—	—	D	3	K+	5
	—	—	—	—	—	—	D	2	—	—
	—	—	—	—	—	—	D	1	—	—
	—	—	—	—	—	—	K+	3	—	—
150–300	K	1	D	2	D	(–)	D	(–)	K	2
	D	(–)	K	2	D	5	K	2	K	3
	K	2	K	2	D	(–)	K	5	K	3
	D	(–)	D	2	K	4	D	5	K	3
	K	2	K	2	K	3	K	5	—	—
	D	(–)	K	2	K	5	—	—	—	—
	D	2	K	3	K	5	—	—	—	—
	—	—	—	—	K	4	—	—	—	—
301–365	K	2	D	(–)	K	4	K	3	K	2
	K	3	D	5	K	4	K+	5+	K	4
	K	1	K	1	K	1	K	3	K	1
	K	1	K	1	K	5	—	—	K	5
	K	1	K	3	K	1	—	—	K	3
	K	1	K	2	K	3	—	—	K	5
	K+	2+	K	3	K	5	—	—	K+	5+
	K	1	K	3	K+	5+	—	—	K	5
	—	—	K	2	—	—	—	—	—	—
	—	—	K+	3+	—	—	—	—	—	—
	—	—	K	2	—	—	—	—	—	—

+ Sections from these animals are reproduced in figures.
K = killed, D = died. * Max. = maximal, min. = minimal within the indicated group of fibrosis.
(–) Lost through cannibalism

PATHOLOGICAL FINDINGS

Sections were examined microscopically, and the fibrosis present in the most advanced lesions from any pair of lungs has been graded according to Belt and King (1945). The pathological gradings, so obtained, along with the duration of the experiments and the days of survival of the animals, have been summarized in Tables 2 and 3. The basis of the pathological gradings was as follows : grade 1, loose reticulin fibrils with no collagen ; grade 2, compact reticulin with or without some collagen ; grade 3, somewhat cellular, but made up mostly of collagen ; grade 4, completely acellular and fully collagenous ; grade 5, acellular, confluent, and collagenous. It should be noted that in this classification the stages 1 to 4 measure increasing maturity of the silicotic lesions. Progression to stage 5 indicates confluence and depends therefore to some extent on the amount of the lesions, which will depend on the amount of dust introduced as well as on its distribution.

Gross Appearance of the Lungs

In the constant-amount series the appearance of the lungs was very variable within the individual groups. The animals having the largest two sizes of the dust (4–8μ and 2–4μ) showed only small lesions in the lungs. Pin-head, whitish spots were seen discretely scattered over the surface of the lung. No appreciable change was seen till late in

TABLE 3

ASSESSMENT OF FIBROSIS IN SECTIONS OF LUNGS OF RATS PRODUCED BY A CONSTANT SURFACE AREA (700 cm.²) FROM DIFFERENT AMOUNTS OF DIFFERENT PARTICLE SIZES OF FLINT DUST

Size Amount	4–8μ 199 mg.		2–4μ 100 mg.		1–2μ 42·5 mg.		0·5–1μ 17·5 mg.		<0·5μ 8 mg.	
Days of Survival	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis	Mode of Death	Degree of Fibrosis
1–30	K	2	K	2	K	1	D	Infective	K	1
	K+	2	K+	3 min.*	K+	3	K	1	K+	3
	—	—	—	—	—	—	K+	3	—	—
31–60	K	2	K	3	K	3	K	3	K	3
61–90	K	2	K	3	K	3 max.*	K	3	K	3 min.
91–120	D	(–)	K	3	K	3	K	3	K	3
	K	2	K	4	K	4 min.	K	3 max.	K	3
121–150	D	(–)	K	4	D	(–)	K	3	D	3
	K	2	K+	4 min.	K	4	—	—	K	3
	K+	2	—	—	K+	4	K+	3 max.	K+	3
151–180	K	2	D	4 min.	D	5	K	3	K	3
	K	2	D	5	K	5	K	3	K	3
	—	—	K	5	K	5	—	—	—	—
	—	—	K	5	—	—	—	—	—	—
181–210	D	2	D	(–)	K	5	K	3	K	3
	D	(–)	D	(–)	K	5	K	3	K	3 min.
	K	2	K	5	—	—	—	—	—	—
	K	2	K	5	—	—	—	—	—	—
211–240	D	2	K	5	K	5	K	4	K	3
	K	2	K	5	K	5	K	4	K	3
	K	3 min.	—	—	—	—	—	—	—	—
241–270	K	3 min.	D	(–)	K	5	K	4	D	(–)
	K	3 min.	K	5	K	5	K	4	K	3
	—	—	K	5	—	—	—	—	K	3
271–300	D	(–)	K	5	D	5	K	4 max.	K	2 max.
	K	2 max.	K+	5	D	(–)	K+	5	K+	4 min.
	K+	3 min.	—	—	K	5	—	—	—	—
	—	—	—	—	K+	5	—	—	—	—
301–365	D	(–)	D	(–)	D	(–)	D	(–)	K	3 max.
	K	3	K	5	D	(–)	D	(–)	K	*a*
	K	*a*	K	*a*	K	5	D	(–)	K	*a*
	—	—	—	—	K	*a*	K	4 max.	—	—
	—	—	—	—	K	*a*	K	*a*	—	—
	—	—	—	—	—	—	K	*a*	—	—
366–400	D	(–)	K	5	K	5	D	(–)	K	3 max.
	K	3	—	—	—	—	D	(–)	—	—
	—	—	—	—	—	—	K	4 max.	—	—
401–450	K	3	D	5	D	5	D	5	K	*a*
	—	—	K	*a*	K	*a*	K	*a*	K	4 min.
451–500	K	3	D	5	—	—	—	—	K	*a*
	—	—	—	—	—	—	—	—	K	*a*
	—	—	—	—	—	—	—	—	K	3 max.
	—	—	—	—	—	—	—	—	K	*a*

+ Sections from these animals are reproduced in figures.
K = killed, D = died. * Min. = minimal, Max. = maximal within the indicated group of fibrosis.
(–) Lost through cannabilism.
a Used for analysis.

the experiments, when they became slightly larger, about 2 to 3 mm. in diameter. The next two sizes of the dust (1–2μ and 0·5–1μ) produced, within a few weeks, small and discrete lesions, which progressed gradually so that by the eighth month confluence was noted. In the case of the smallest particle size (<0·5μ) the lesions were large and irregular from the beginning. They were about 2 to 4 mm. in diameter and by the fifth month firm and rubbery patches of confluent fibrosis were seen. Pleural involvement was more marked in the groups of animals receiving the smaller sized dust particles.

In the constant-surface series a different picture was produced. Early in the experiment all the groups showed essentially similar lesions, which were large and irregular, about 2 to 4mm. in diameter, and greyish-white. Hardly any change occurred, with time, in the lesions in the 4 to 8μ group, although their number increased. The lesions steadily grew in size in the two groups of animals receiving 2–4μ

and 1–2μ particle-size dust, and by the sixth month coalescence of the nodules was noticed, especially in the posterior aspects of the lungs, the areas being firm and rubbery. In the two groups of animals having the smallest particle-size dust (0·5–1μ and <0·5μ) there was some increase in size of the lesions towards the end of the experiments. The pleura was inflamed in patches in all the groups, more markedly with the smaller sizes of particles.

The posterior aspects of the lungs appeared to be more frequently involved than the anterior. The tracheo-bronchial lymph glands were enlarged to several times their normal size in most of the experimental animals, except with the largest size class. As this finding appeared significant a detailed study of the lymph glands has been undertaken. This will be described in a following paper.

The animals that died within about a month from the beginning of the experiments had dark, partly consolidated lungs, but later in the experiment greyish lesions, either in spots or in streaks, were visible within such dark areas.

Microscopic Appearance of the Lungs

Constant-amount Series.—A large variation in the rate and severity of tissue reaction to equal amounts of the five different sizes of flint dust was seen in the lungs of the experimental animals. Although there were discrepancies within individual groups of animals, still, on the whole, the smaller the particle size of the dust the more severe and quicker was the tissue reaction to it. The largest two sizes of the dust (4–8μ and 2–4μ) were slow to produce a fibrous reaction. Early in the experiment the lesions were essentially similar for both, i.e., a fine focal type of reticulin fibrosis in about 30 days, which was only about grade 1 minimal. As the experiment proceeded there was only a slight increase of fibrosis (grade 2) with the largest particle-size dust (4–8μ); but a gradual progression to a moderate degree of fibrosis (grade 3) was seen in the case of the 2–4μ particles. The next two fractions (1–2μ and 0·5–1μ) produced almost equal changes in the lungs. Although the maximum fibrosis was produced by these dusts, the degree of severity appeared to be delayed when compared with the finest particle size. There was only a mild degree of grade 2 fibrosis in one month, but the nodules progressed steadily and had coalesced in about eight months to grade 5 fibrosis. The smallest particles (<0·5μ) produced, in a month, a severe degree of pulmonary fibrosis (grade 4), and confluence of nodules was seen after only five months.

Constant-surface Series.—In the second (constant surface) series the fibrogenic reaction in the lungs of the rats was most severe within the range of 1 to 4μ particles, less so below 1μ and least with 4–8μ. The earlier reactions were essentially the same (grade 3 fibrosis) with all except the largest particle size, which produced slightly less fibrosis (grade 2). As the experiment proceeded the lesions advanced steadily in the groups of animals receiving 1–2 and 2–4μ particles, so that in 120 days the maximum degree of fibrosis (grade 5) was produced. In the case of 0·5–1μ particles the progress was slower and the maximum degree (grade 5) was not reached till 300 days. No further appreciable change was noticed in the groups of animals injected with the <0·5μ and 4–8μ dusts till the end of the experiments when some increase of fibrosis was seen in both (grade 4 early and grade 3 early respectively).

Detailed Histological Findings

Constant-amount Series.—The series is considered in groups according to particle size.

Flint : 4–8μ (50 *mg.*).—This largest sized flint dust was least pathogenic in the animal lungs. A mild degree of fibrosis (grade 2) was seen at 270 days, and it did not progress any further till the end of one year.

Although the dust cell reaction was quite prominent in the lungs of animals that died within three weeks of the injections, no fibrosis was seen in any. Well defined, rounded aggregations of dust cells were seen in sections at 30 days, but the reticulin fibres were fine and loosely woven (grade 1 fibrosis, Fig. 2). At 87 days the lesions were assessed as grade 2 early ; otherwise the fibrosis remained as grade 1 (Fig. 7) up to 270 days, when the nodules became more fibroblastic. The reticulin fibres within such nodules were coarse and compact, and there was some collagen formation (grade 2 fibrosis). Sections examined at 330 days and 365 days showed similar changes (grade 2 fibrosis, Fig. 12), and some of the rats killed at 365 days had rather less severe lesions.

Flint : 2–4μ (50 *mg.*).—Only a moderate degree of pulmonary fibrosis (grade 3) was produced by this particle size in about a year. Although the earlier reaction was almost the same as with smaller sized particles (grade 1 maximal, 30 days) further progress was much slower.

The lungs of the two rats that died 10 and 24 days after the injections showed good dust cell reaction with small collections of dust cells without any evidence of increase of reticulin fibres within aggregations. The nodules were well formed by

the thirtieth day and a loose network of thick reticulin fibres was seen in some of them (grade 1 fibrosis, maximal, Fig. 3). At 90 days the fibrosis was similar. Sections examined on the 150th day showed larger cellular nodules, the centres of which were closely packed with coarse reticulin fibres, but in the periphery they were loosely woven (grade 2 fibrosis, Fig. 8). The same degree of fibrosis was seen in the sections from all rats which died or were killed between this period and 300 days, when some nodules were found to be slightly cellular and almost collagenous (grade 3 fibrosis). At 330 days the lesions were fewer and less advanced. In the eight rats killed at 365 days grade 3 fibrosis of the lungs was seen in four (Fig. 13) and the rest showed rather less. Pleural surfaces were almost free except for a few tiny patches of thickening.

Flint : 1–2μ (50 *mg.*).—Steadily progressive, classical silicosis was produced in the lungs of experimental animals by this size of flint dust (grade 2 fibrosis at 30 days, grade 3 at 150, and grade 5 at 270 days).

In the sections examined from the lungs of the first rat that was killed, 30 days after the injections, large nodules composed mainly of fibroblasts were seen. Such nodules were tightly packed with coarse reticulin fibres (grade 2 fibrosis, Fig. 4). By the sixtieth day the lesions became partly acellular and more collagenous (grade 3 fibrosis, early). At 150 days they were only slightly cellular and almost fully collagenous (grade 3 fibrosis, Fig. 9). The fibrosis progressed steadily so that by 270 days completely acellular and hyalinized areas were seen. These areas were fully collagenous (grade 5 fibrosis). There was some variation in the lung pathology in this group, especially among the rats that died. Although all the animals after this period did not maintain this degree of fibrosis, some at 365 days showed grade 5 (Fig. 14). There were a few small patches of pleural thickening over the underlying nodules. Lung fields in most of the killed rats were almost clear. Hilar lymph nodes in some cases showed good dust cell reaction.

Flint : 0·5–1μ (50 *mg.*).—The rate of reaction appeared to be about the same as for the previous (1–2μ) fraction, but less rapid than with the following one (<0·5μ). Nodular fibrosis of grade 2 and acellular confluent fibrosis of grade 5 were produced in 30 and 240 days respectively.

One rat which died six days after the injections showed a good dust cell reaction in its lungs. Some dust-laden phagocytes lay within the alveoli. Small dust-cell aggregations were seen in sections at 12 days, within which some fine reticulin fibres were noted (grade 1 fibrosis). Sections examined on the thirtieth day showed larger cellular nodules with coarse reticulin fibres and some collagen (grade 2 fibrosis, Fig. 5). The rats, killed at intervals from this period to the end of one year, showed steady progression of fibrosis, but the reaction was variable. At 150 days partly acellular and almost fully collagenous nodules were seen (grade 3 fibrosis, Fig. 10). By the 240th day there was confluent collagenous fibrosis. This was maintained in the rest of the rats (Fig. 15), except one at 365 days, which showed only grade 3 fibrosis. The pleural involvement and dust cell reaction within hilar lymph nodes were almost the same as in the previous and following groups.

Flint : <0·5μ (50 *mg.*).—Coarse reticulin fibrosis (grade 2) was produced in the lungs of rats in 18 days by this size of the dust. The fibrosis rapidly progressed to the maximum degree (grade 5) by 150 days.

The first rat died 18 days after the injections, and showed in its lungs large stellate cellular nodules and plenty of free dust cells. There was some exudation involving small groups of alveoli. Reticulin fibres within these nodules were thick and closely packed (grade 2 fibrosis, Fig. 6). By the end of the third week the lesions were only slightly cellular and more collagenous. They became completely acellular and hyalinized at 31 days. On reticulin staining such nodules were fully collagenous (grade 4 fibrosis), except in animals at 84 and 94 days, when grade 3 fibrosis was found. Other rats showed similar lung changes up to 150 days, when confluence of hyalinized collagenous areas was found (grade 5 fibrosis, Fig. 11). Some variation in the degree of fibrosis was noted in the lungs of rats that were killed after this period, and until the end of one year, all of them being less than grade 5 fibrosis. However, of the six rats killed on the 365th day, three had grade 5 fibrosis (Fig. 16). The pleura was badly involved in this group. Nearly the whole surface was thickened. Free dust cells were seen all through the experiment, and hilar lymph nodes showed prominent dust cell reaction in some cases.

Constant-surface-area Series.—For the constant-surface-area the grouping by particle is the same as for the constant-amount series.

Flint : 4–8μ (199 *mg.*).—The earliest reaction induced by these maximum-sized particles was as severe and rapid as in the case of the next lower size, i.e., 2–4μ particles (grade 2 at 21 days), but no further progress of the fibrosis was seen till late in the experiment, and then only to grade 3 at 300 to 500 days.

Sections from the lungs of the first rat, killed 21 days after the injections, showed a great number of large cellular nodules, the cells being mainly fibroblasts. Compact reticulation of such nodules, with coarse reticulin fibres and some collagen fibres, was seen in silver-impregnated preparations (grade 2 fibrosis). Plenty of free dust cells were present throughout the lung fields. No further advance of fibrosis was seen in any of the rats, killed or dead, until 240 days (Fig. 17 at 30 days and Fig. 22 at 150 days). One of the two rats killed at 240 days showed in its lungs a few nodules of more advanced fibrosis ; these were slightly cellular and almost collagenous (grade 3 fibrosis, early). Similar pathological changes were seen in sections examined at 270 and 500 days (Fig. 27).

Flint : 2–4μ (100 *mg.*).—This and the next size of dust (1–2μ) produced lung lesions which were very similar in rate and severity (grade 3 at 30 days, 4 at 120, and 5 at 180 days).

The reaction produced at 21 days was a little heavier than in the following groups by the same time. The larger irregular nodules were highly cellular, the cells mainly fibroblasts. The reticulin fibres within these were coarse and compact. Some collagen fibres were seen in a few nodules (grade 2 fibrosis). Plenty of free dust cells, singly or in small groups, were seen in some alveoli and parenchymal tissue. Although the majority of the nodules remained cellular, some were slightly less so, and these were somewhat collagenous at 30 days (grade 3 fibrosis, early, Fig. 18). The changes were similar in sections examined on 60 and 90 days, and from one of two rats killed at 120 days. The other rat at 120 days showed more progressive lung lesions which were completely acellular, hyalinized, and fully collagenous (grade 4 fibrosis). The lesions remained within the maximum limit of grade 4 fibrosis at 150 days (Fig. 23) but they became confluent by 180 days (grade 5 fibrosis). All the rats killed between this period and 500 days showed similar pathological lesions in the lungs (Fig. 28). The three rats which died during this period were lost by death and cannibalism.

Flint : 1–2μ (42·5 *mg.*).—The early reaction was very rapid (as rapid as with the smaller sized particles and more rapidly progressive). Grade 3 fibrosis was reached at 30 days, grade 4 at 120, and grade 5 at 180 days.

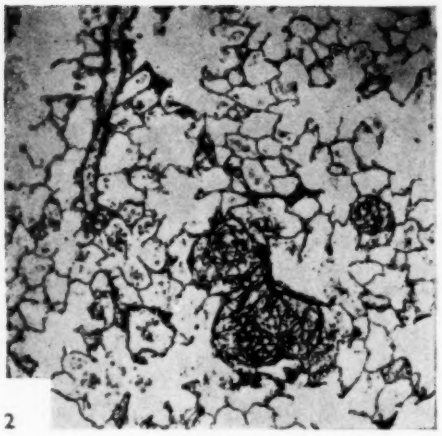
Sections from the lungs of rats at 21 and 30 days showed, respectively, grade 1 fibrosis of loose reticulin meshwork and grade 3 fibrosis of almost completely collagenous nodules (Fig. 19). No further appreciable increase in the degree of fibrosis was seen until after 120 days, when one of the two rats killed showed in the lungs a few acellular, hyalinized, fully collagenous nodules (grade 4 fibrosis, early). By 150 days more nodules became acellular and collagenous (grade 4 fibrosis, Fig. 24). The lesions were confluent in sections examined at 180 days (grade 5 fibrosis), and this grade of fibrosis was maintained in all the rats dead or killed between this period and 450 days (Fig. 29).

Flint : 0·5–1μ (17·5 *mg.*).—The early reaction produced by this size of the dust was about as rapid as in the preceding (larger) and following (finest) particle sizes. The fibrosis progressed slowly to the maximum degree of confluent fibrosis (grade 5) in 300 days.

The first rat that died seven days after the injections was excluded from the series, as the lungs were highly infected. Sections from the lungs of the rats killed at 21 days showed grade 1 fibrosis, of loosely woven reticulin fibres ; and all other rats killed from 30 days (Fig. 20) up to 210 days showed collagenous grade 3 fibrosis, except at 120 and 150 days, when the fibrosis was maximum within that grade (Fig. 25). At 240 days completely acellular and hyalinized nodules, which were fully collagenous with reticulin stain, were seen (grade 4 fibrosis). This degree of fibrosis was maintained until 300 days, when confluence of such nodules was noted in one of the two rats killed (grade 5 fibrosis, Fig. 30).

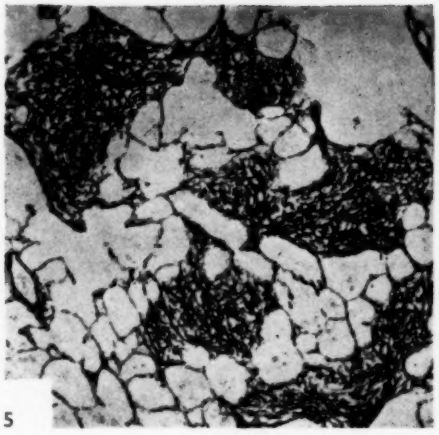
Flint : $<$0·5μ (8 *mg.*).—A moderately severe degree of pulmonary fibrosis (grade 3) was produced by this dust as early as a month, but it remained absolutely non-progressive till 300 days when some advancement of the lesions was noted (grade 4 fibrosis, early).

Sections from the rat that was killed three weeks after the injection showed well formed, rounded dust cell aggregations, mainly in the peripheral zone of the lung. Lung fields were clear ; no exudation was present. On silver impregnation fine reticulin fibres of a loose network were seen within such nodules (grade 1 fibrosis). The progression of fibrosis was rapid at this stage. At 30 days the lesions were moderately large and irregular. They were composed mainly of fibroblasts. Some nodules were only slightly cellular. Although the majority of the nodules were closely packed with coarse reticulin fibres with a little collagen formation, the few slightly acellular nodules were almost collagenous (grade 3 fibrosis, Fig. 21). After this period until 270 days very little change in the progress of fibrosis was seen. Most of the nodules, however, matured within the limits of grade 3 fibrosis (Fig. 26). No tissue was taken for histology from



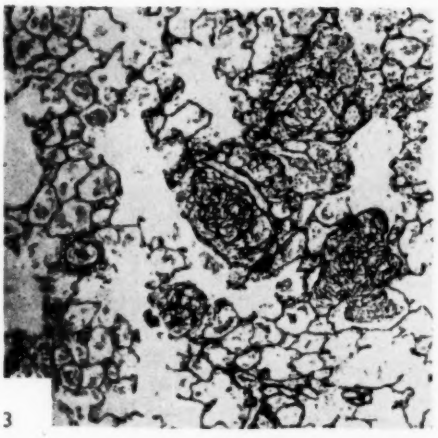
2

4–8μ



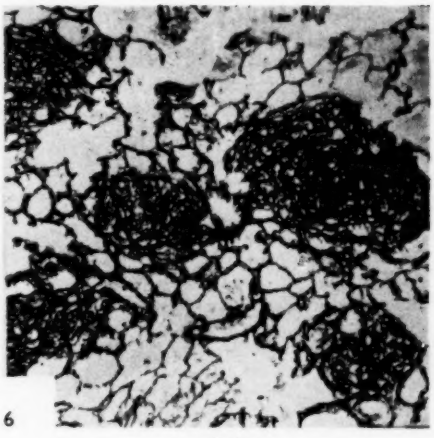
5

0·5–1μ



3

2–4μ



6

<0·5μ

4

1–2μ

Sections of lungs 30 days after the injection of constant weights (50 mg.) of flint dusts of different sizes. Silver impregnation × 90, showing reticulin nodules.

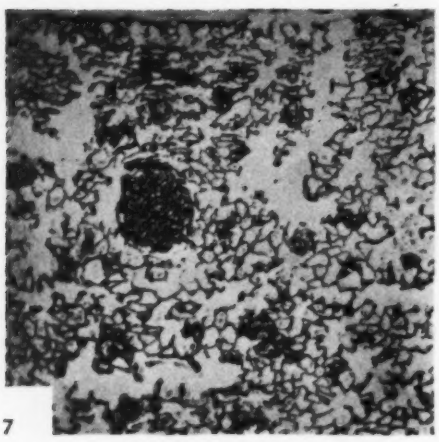
FIG. 2.—Loosely woven fine reticulin fibres. Grade 1 fibrosis.

FIG. 3.—Loose network of thick reticulin fibres. Grade 1 fibrosis maximal.

FIG. 4.—Tightly packed coarse reticulin fibres. Grade 2 fibrosis.

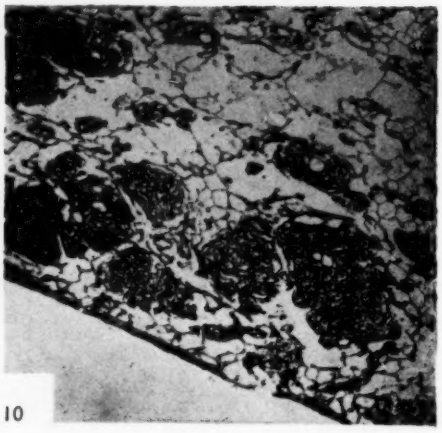
FIG. 5.—Coarse reticulin fibres and some collagen. Grade 2 fibrosis.

FIG. 6.—Eighteen days. Thick and compact reticulin fibres Grade 2 fibrosis.



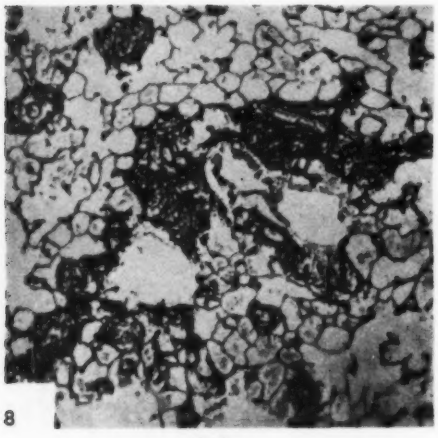
7

4–8μ



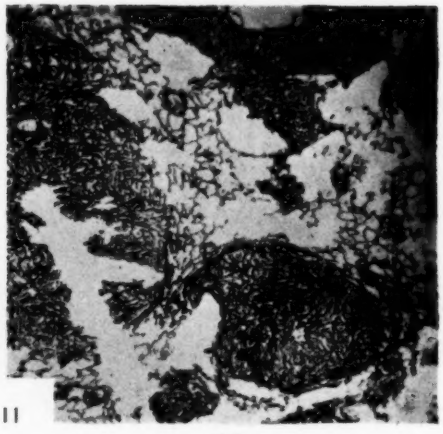
10

0·5–1μ



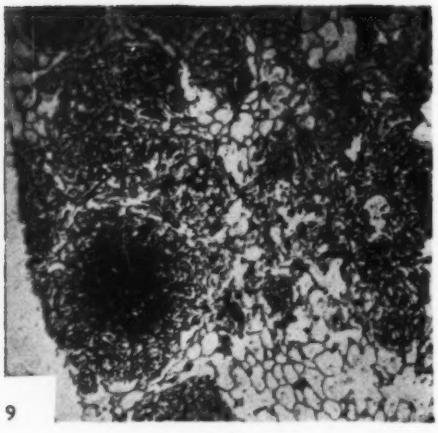
8

2–4μ



11

<0·5μ



9

1–2μ

Sections of lungs 150 days after the injection of constant weights (50 mg.) of flint dusts of different sizes. Silver impregnation × 50.

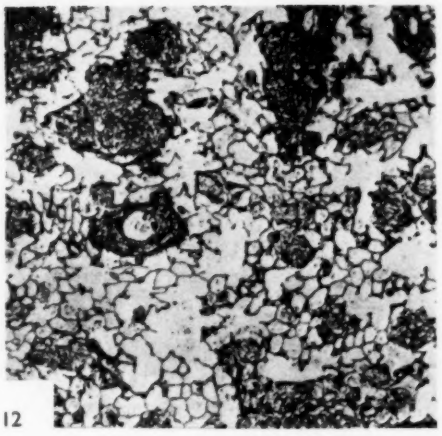
FIG. 7.—Scattered nodules of grade 1 fibrosis.

FIG. 8.—Closely packed reticulin fibres in centres of nodules, but loose at periphery. Grade 2 fibrosis.

FIG. 9.—Almost fully collagenous nodules, slightly cellular with ordinary nuclear stain. Grade 3 fibrosis.

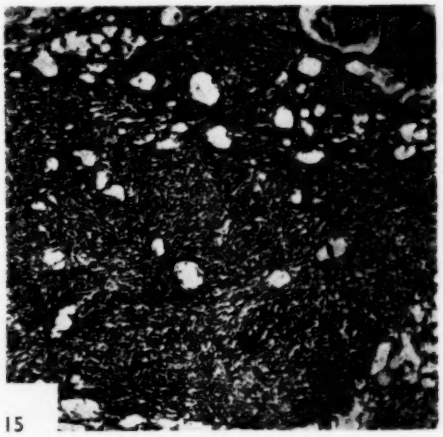
FIG. 10.—Almost fully collagenous nodules, partly acellular. Grade 3 fibrosis.

FIG. 11.—Confluent collagenous fibrosis of grade 5.



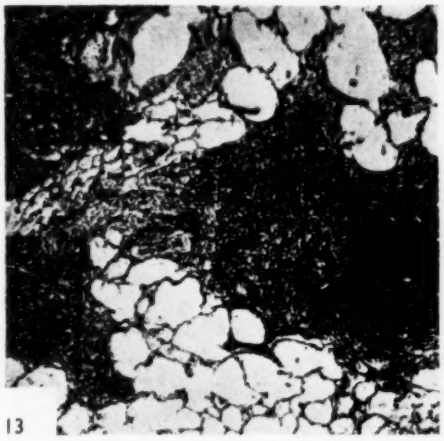
12

4–8μ



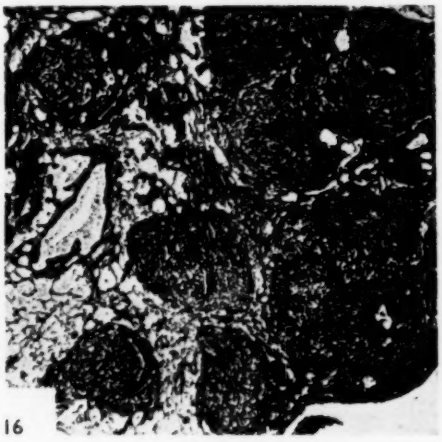
15

0·5–1μ



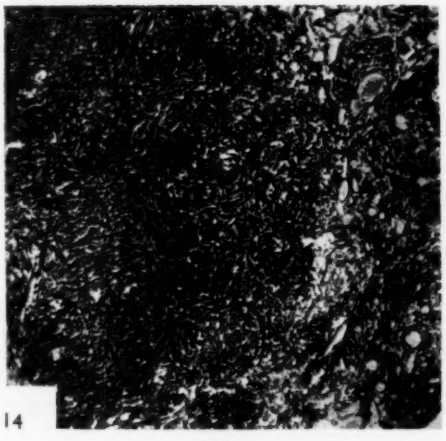
13

2–4μ



16

<0·5μ



14

1–2μ

Sections of lungs 365 days after the injection of constant weights (50 mg.) of flint dusts of different sizes. Silver impregnation × 40.

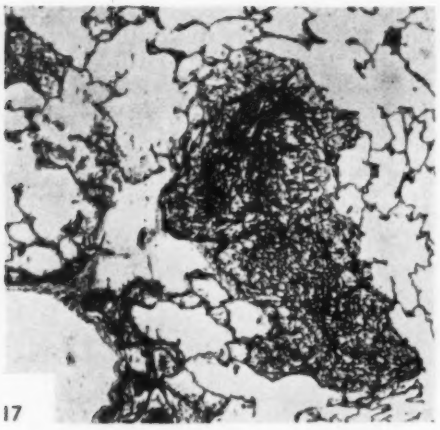
FIG. 12.—Nodules with coarse and compact reticulin fibres and some collagen fibres. Grade 2 fibrosis.

FIG. 13.—Almost fully collagenous nodules, slightly cellular with ordinary nuclear stain. Grade 3 fibrosis.

FIG. 14.—Confluent collagenous fibrosis of grade 5.

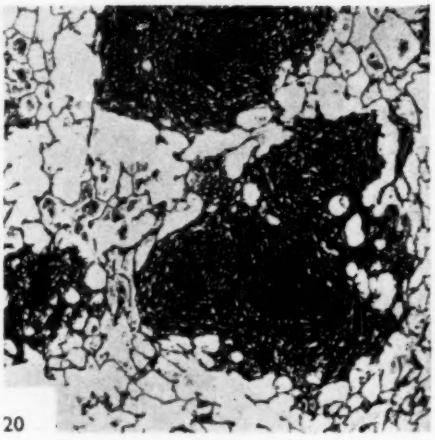
FIG. 15.—Confluent collagenous fibrosis of grade 5.

FIG. 16.—Confluent collagenous fibrosis of grade 5.



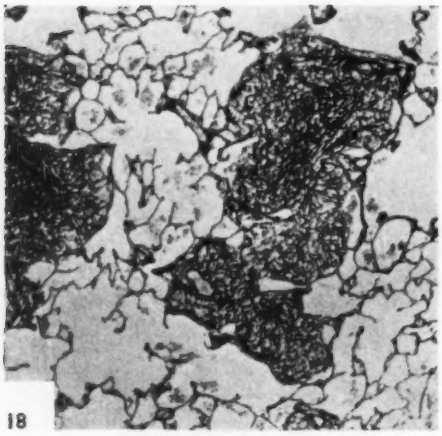
17

4–8μ



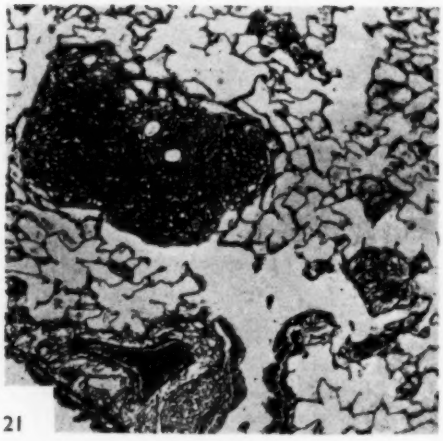
20

0·5–1μ



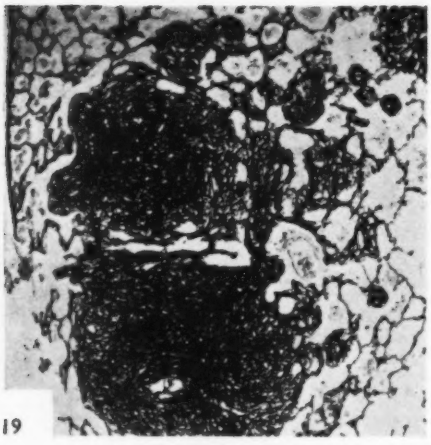
18

2–4μ



21

<0·5μ



19

1–2μ

Sections of lungs 30 days after the injection of constant "areas" (700 cm.²) of flint dust of different sizes, given in amounts calculated to yield the same area of particle surface. Silver impregnation × 66.

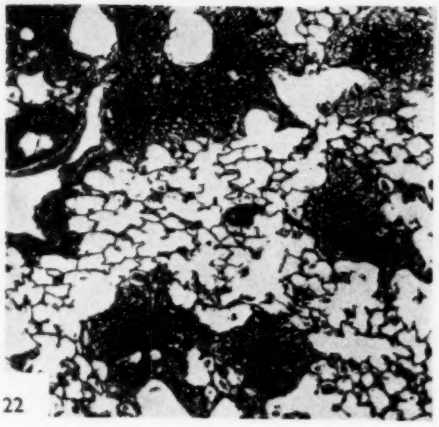
FIG. 17.—199 mg. of 4–8 μ. Nodules with coarse and compact reticulin fibres and some collagen. Grade 2 fibrosis.

FIG. 18.—100 mg. of 2–4 μ. Somewhat collagenous nodules, partly acellular with ordinary nuclear stain. Grade 3 fibrosis, early.

FIG. 19.—42·5 mg. of 1–2 μ. Almost fully collagenous nodules, slightly cellular. Grade 3 fibrosis, maximum.

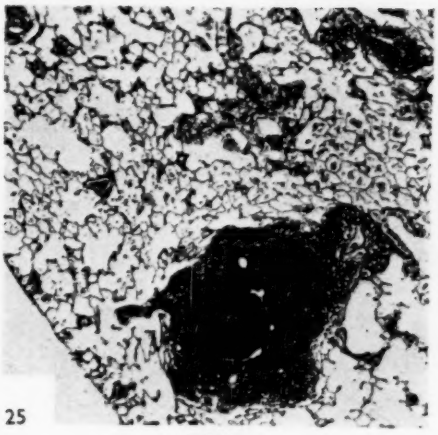
FIG. 20.—17·5 mg. of 0·5–1 μ. Almost fully collagenous nodules, slightly cellular. Grade 3 fibrosis, maximum.

FIG. 21.—8 mg. of < 0·5 μ. Almost collagenous nodules, slightly cellular. Grade 3 fibrosis.



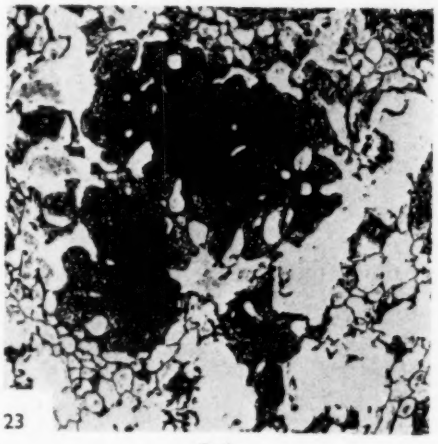
22

4–8μ



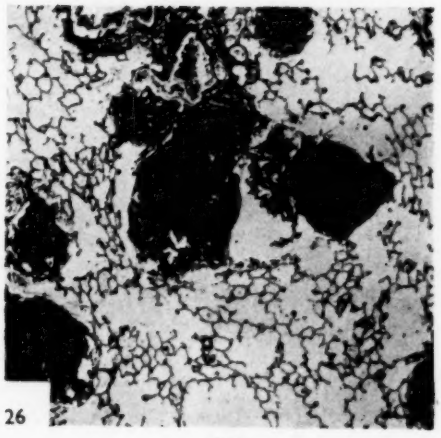
25

0·5–1μ



23

2–4μ



26

<0·5μ

24

1–2μ

Sections of lungs 150 days after the injection of constant "areas" (700 cm.²) of flint dust of different sizes, given in amounts calculated to yield the same area of particle surface. Silver impregnation × 40.

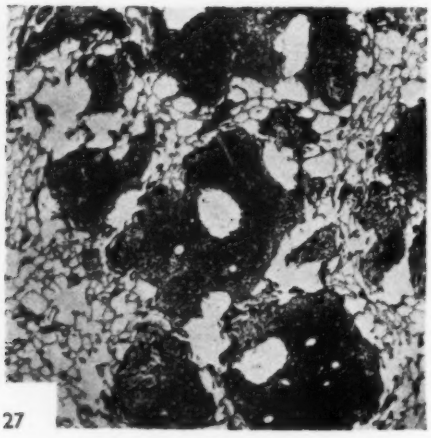
FIG. 22.—199 mg. of 4–8 μ. Nodules of grade 2 fibrosis.

FIG. 23.—100 mg. of 2–4 μ. Fully collagenous nodules, completely acellular with ordinary nuclear stain. Grade 4 fibrosis, minimal.

FIG. 24.—42·5 mg. of 1–2 μ. Fully collagenous nodules, completely acellular. Grade 4 fibrosis.

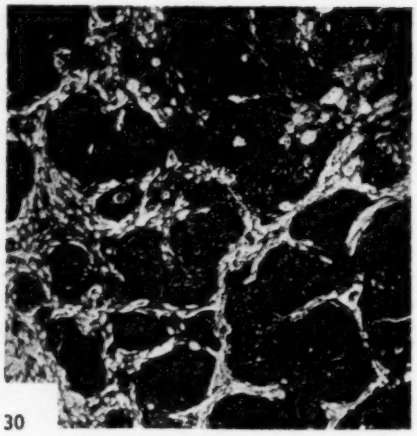
FIG. 25.—17·5 mg. of 0·5–1 μ. Almost collagenous nodules, slightly cellular, Grade 3 fibrosis, maximal.

FIG. 26.—8 mg. of < 0·5 μ. Almost collagenous nodules of grade 3 fibrosis.



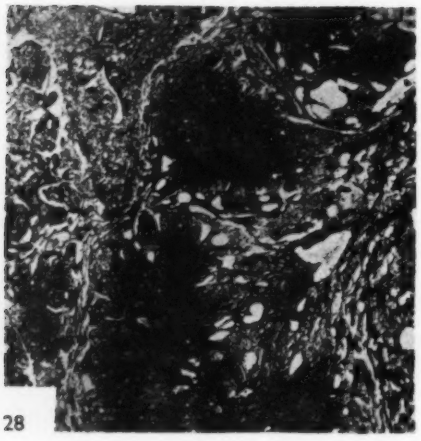
27

4–8μ



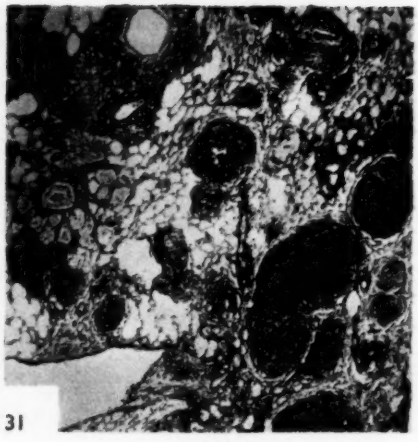
30

0·5–1μ



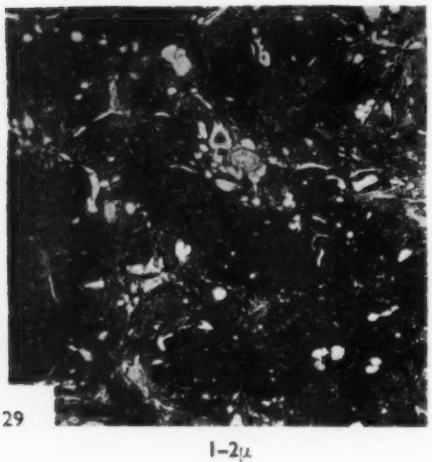
28

2–4μ



31

<0·5μ



29

1–2μ

Sections of lungs 300 days after the injection of constant "areas" (700 cm.²) of flint dust of different sizes, given in amounts calculated to yield the same area of particle surface. Silver impregnation × 30.

FIG. 27.—199 mg. of 4–8 μ. Almost collagenous nodules, partly acellular with ordinary nuclear stain. Grade 3 fibrosis, early. (× 50).

FIG. 28.—100 mg. of 2–4 μ. Complete collagenous fibrosis of grade 5.

FIG. 29.—42·5 mg. of 1–2 μ. Confluent collagenous fibrosis of grade 5.

FIG. 30.—17·5 mg. of 0·5–1 μ. Confluent collagenous fibrosis of grade 5.

FIG. 31.—8 mg. of < 0·5 μ. Fully collagenous nodules, completely acellular. Grade 4 fibrosis early.

one rat that died at 244 days, owing to almost complete replacement of its lungs by abscess formation. At 300 days sections from one of the two rats that were killed showed rather less marked fibrosis than previous ones, but a few completely acellular and fully collagenous nodules were present in the lung sections from the other rat. They were assessed respectively as grade 2 maximal and grade 4 early fibrosis (Fig. 31). Between 350 and 500 days three rats showed stage 3 or 4 minimum.

DISCUSSION

The object of the present work was to get as precise information as possible on the effect of size and surface area on the grade of fibrosis produced in the lungs of rats in injection experiments. There should be a lower size limit somewhere between 1 and 0·01μ (Nagelschmidt, 1949), and it was thought that it might be possible to reach it experimentally. Also there was no information on what the reaction would be if samples representing equal surface areas, but composed of different size classes, were injected.

In theory it should be possible to make similar experiments on the basis of equal particle numbers. However, it would not be possible in practice to cover such a wide range of sizes. To give equal particle numbers each succeeding fraction in the present flint series would have to be given at about one tenth the weight of the next larger fraction.

Preparation of samples is a major difficulty in such work. In any grinding process quartz gets contaminated, and quartz sands usually contain clay as impurities. Both types of contamination will accumulate in the finest size fractions. For this reason calcined flint was used in the present experiment. This flint consisted of quartz and cristobalite, but recent work by ourselves (1953) has shown that these two modifications of silica have very similar fibrogenic properties.

Assessment of fibrosis is ideally based on maturity of the lesions and total amount of fibrosis. In the present study only the degree of fibrosis classified into five stages as outlined above has been used. It is possible to measure fibrosed areas on tissue sections, but the uneven development of fibrosis throughout the lung makes such measurements valueless unless a very large number of sections is made. It may be possible to develop in the future biochemical or radiographic methods to assess the total amount of fibrosis per lung.

Constant-amount Series (50 mg. Flint per Rat)

The main results can be summarized as follows :

Flint Size (μ)	Silica Solubility (mg./100 ml.)	Surface per Rat (cm.²)	Maximum Stage of Fibrosis	Reached after Months	Minimum Time (Months) to Give Stage			
					2	3	4	5
4–8	5·1	170	2	9	9	—	—	—
2–4	8·9	350	3	10	5	10	—	—
1–2	13·1	750	5	9	1	5	7	9
0·5–1	13·4	2,000	5	7	1	2	3	7
<0·5	13·6	3,000	5	5	<1	<1	1	5

There is a regular increase in activity as the particle size decreases and the differences are large. The smaller the mean size of flint the faster or more advanced is the tissue reaction, if equal weights are injected.

Constant-surface Series

The same samples given on an equal surface basis gave more homogeneous results when 700 cm.² of flint per rat gave different fibrosis stages after the following number of months :

Flint Size (μ)	Weight of Dust per Rat (mg.)	Minimum Time (Months) to Give Fibrosis Stage		
		3	4	5
4–8	199	8	—	—
2–4	100	1	4	6
1–2	42	1	4	5
0·5–1	17·5	1	7	10
<0·5*	8	1	10	—

* This sample represents 520 cm.².

The largest fraction only just reached stage 3 and the smallest fraction stage 4. Thus this series seems to demonstrate that there is an optimum fibrogenic size in the region of 1 to 2μ under our experimental conditions.

At the time the injections were made no facilities were available to measure the surface area of the fraction below 0·5μ, and its surface area had been over-estimated. The 8 mg. injected actually represented only 520 cm.² and this dose failed to produce stage 5 (confluent) fibrosis. This may suggest that a minimum weight, as well as a minimum of silica surface, is required to produce stage 5, which, as explained above, depends on number and size of lesions as well as on their maturity. Because of phagocytosis and dissolution of particles one might say that by the time stage 5 should have been reached there was insufficient silica left to produce it. It may be possible to check this hypothesis by analysing the parts of the rat lungs not used for sectioning. It must be remembered that a larger dose of the same fraction produced stage 5 in only five months.

If the failure of the fraction below 0·5μ. to produce stage 5 fibrosis can perhaps be explained on the ground that the absolute amount was insufficient, there is no simple explanation for the failure of the largest fraction to go beyond stage 3. There was

no difference in the ease of phagocytosis as far as could be judged from the sections, and no other obvious explanation can be seen. Some light may be thrown on this by further work on the lymph nodes.

Assessment of the results is complicated by the fact that the animal technique was changed from single-dose intratracheal injection through an incision in the neck for the "constant-amount" series to multiple dose peroral intratracheal injection for the "constant-surface" series. The fraction 1–2μ, which occurred at similar weights in both series, shows that the oral technique gave fibrosis more quickly. This is confirmed by the results of the two neighbouring fractions. The slower fibrosis and more irregular results obtained in the "constant-amount" experiments may have been due to regurgitation of variable amounts of dust through the nose, which often occurs with this technique immediately after injection, whereas the oral procedure is almost never followed by loss of dust through the nostrils.

The numbers of particles received by the animals in the different groups were grossly different. In the constant-surface experiment, despite the decreasing weight of dust used with decreasing size, the numbers of particles greatly increased. The rats receiving 199 mg. of 4–8μ flint got about 500 million particles, those receiving 42 mg. of 1–2μ got 10,000 million, and those receiving the 8 mg. of the smallest size ($<0{\cdot}5\mu$) got 135,000 million. It might be contended that the largest-size dust (4–8μ) failed to produce severe silicosis because of the small number of particles (if 500 million can be considered small), in spite of the large mass of dust, equal surface, and equal "solubility". But this can certainly not be claimed in respect of the smallest-size ($<0{\cdot}5\mu$) with which less severe fibrosis, and less of it, resulted than with the 1–2μ dust, despite there being enormously more particles, though of less weight but the same surface area and same "solubility". As far as the constant surface experiments are concerned, therefore, we feel justified in concluding that the finest particles of flint dust have been less pathogenic than those in the 1–2μ range which appears to be the most dangerous size in producing lung fibrosis, under the conditions described.

These results support the conception that fibrogenesis is closely related to the silica surface, but they also point to there being a range of maximally fibrogenic sizes. It is hoped to determine in further experiments whether the decrease in pathogenesis of the smallest size classes is also found when the same flint fractions are given at higher surface levels.

SUMMARY

Graded flint samples between $<0{\cdot}5$ and 8μ were given to rats by intratracheal injection on the basis of equal weights (50 mg. per rat), and also on the basis of equal surfaces (700 cm.^{2} per rat).

With equal weights the fibrogenic activity increased considerably with decreasing size. Whereas the largest fraction only gave stage 2 fibrosis in nine months, the smallest one gave stage 5 in five months.

With equal surfaces the largest fraction went only to stage 3 and the smallest fraction to stage 4. The optimum fibrogenic size of flint particles in this type of experiment was between 1 and 2μ equivalent diameter. Possible explanations for the falling off at both size ends are discussed.

The authors are indebted to Dr. D. Roberts, Mr. B. S. C. Hollands, and Mr. W. Weedon for help with the injection of the animals; Mr. Hollands for care of the animals, and cutting of the sections; Mr. J. Cartwright and Mrs. N. Jennison for assessing the size distributions by light and electron microscopy; Mr. O. G. Griffin for the *x*-ray analyses; and Messrs. A. J. Beal and L. Mardlin and Miss V. Pash for the chemical analyses. The photomicrographs are by Mr. E. V. Willmott.

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DUST SAMPLING TO SIMULATE THE HUMAN LUNG

BY

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There are many difficulties associated with sampling an air-borne dust and with assessing its concentration, especially when the potential danger to the lungs is being considered. This is evident from the fact that such a large number of different dust-sampling instruments have been devised from time to time, no two of which give the same results under all conditions. This multiplicity of instruments is due partly to the fact that there is no fundamental agreement on the appropriate index of concentration to represent the pneumoconiosis hazard of a dust; whether it should be in terms of particle number, surface area, or mass. The relationships between these different units depend very much on the size-distribution of the particles in the dust being considered: different instruments sample particles of different sizes with varying efficiencies. Until recently there has not been any satisfactory quantitative information on the manner in which dust particles penetrate as far as the lung alveoli.

It is the purpose of this paper to consider the effect of certain physical parameters of dust particles, e.g. size, density, and shape, on lung deposition. Subsequently, an examination is made of the possibilities of taking dust samples that are representative of the proportional deposition of the different sizes in the lung. Consideration is given to the different units in which concentration may be expressed. In many dust clouds most of the mass occurs in particles too large to penetrate to the lung alveoli. Table 1 gives the size-distribution of a typical coal-dust cloud; the area and mass distributions have been calculated from the number distribution determined with a microscope.

This is a coarse dust from the point of view of the lung. When the size distributions of the dust, the shape, and density of particles are taken into account (see Fig. 5) the lung, i.e., alveolar, deposition has been calculated to be :—

By number	30%
By area	8·4%
By mass	3·0%

As would be expected, the amount of dust deposited in the lung from a dusty environment depends, among other things, on the size-distribution of the dust. The problem becomes, therefore, how to develop an instrument which selects dust particles of different sizes, densities, and shapes in the same proportion as they are deposited in the lung, so to give an estimate of the respirable dust.

The best information available on alveolar deposition is probably that given by Brown, Cook, Ney, and Hatch (1950). They made over 100 tests with human subjects and sampled the dust breathed in and out through the mouth. Respiration rate was controlled with a Drinker respirator to 15 a minute, the volume per breath varying from 600 to 800 ml. The exhaled dust was partitioned into a number of fractions so that the alveolar fraction could be separated from that coming from different parts of the upper respiratory system. Other investigators have not made this refinement, and with the exception of Wilson and LaMer (1948) have not been able to report more than the retention

TABLE 1

PERCENTAGE DISTRIBUTIONS OF PARTICLE NUMBER SURFACE AREA, AND MASS WITH PARTICLE "DIAMETER" FOR A TYPICAL SOUTH WALES COAL-MINE DUST CLOUD

Size Group (μ)	Number	Surface Area	Mass
<1*	28·9	0·7	—
1–2	21·0	3·3	0·5
2–4	34·6	19·8	4·7
4–8	11·9	30·1	12·8
8–16	3·0	26·6	28·0
16–32	0·575	12·9	26·0
32–64	0·025	5·7	21·0
>64	0·005	0·9	7·0

*Size of particle is given in terms of mean projected diameter. The area and mass distributions have been computed on the assumption that there is no statistical change of shape of particle with size. The dust code number is A(i) of Table 3.

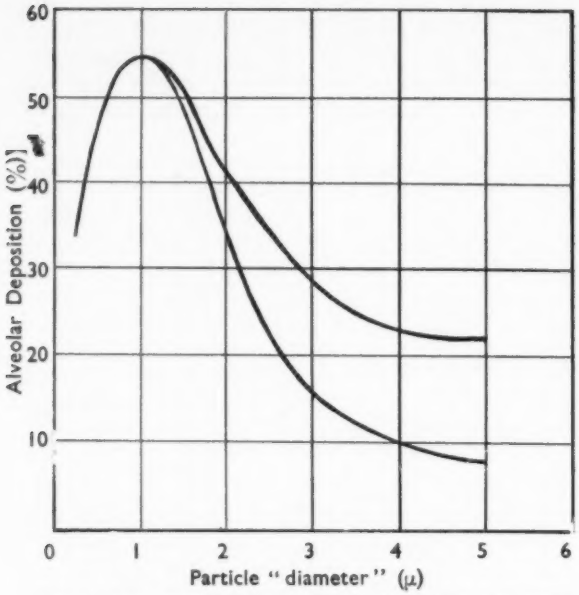

FIG. 1.—Lung deposition curves (Brown, Cook, Ney, and Hatch, 1950) china clay particles ($\rho = 2{\cdot}60$).

of the respiratory system as a whole, or of the nose separately. Wilson and LaMer estimated deposition in the alveoli and lower air passages by direct activity counts on the chest, using radioactive dusts of known size.

Brown and others derived from their measurements the two full curves shown in Fig. 1. The upper curve was calculated on the assumption that upper-respiratory deposition was equal in both directions ; the lower curve is based on an assumed one way upper-respiratory retention. The authors consider the true relationship to lie somewhere between the two. It will be noticed that the curves do not extend to particles smaller than 0·25 μ or larger than 5 μ diameter, and that they tend to flatten out in the approach to the larger sizes. Davies (1949, 1952) in reviewing the literature has stated that spherical particles of unit density larger than 12 μ are completely retained in the nose. Accepting this value for the present purpose, we can say that nothing larger than this will penetrate to the alveoli, but that smaller particles do stand a chance of doing so. It is probable that even with mouth breathing the maximum size penetrating as far as the alveoli remains much the same.

Physical Parameters of Dust Particles

In order to discuss quantitatively the deposition of dust and the significance of the curves shown in Fig. 1 (and so to derive design data for dust-sampling instruments to give directly a measure of hazard), it is necessary to consider something of the physical make-up of dust particles. It is usual to refer to the " diameter " of a particle as a characteristic of its size. The looseness of this custom is at once apparent from Fig. 2, which is a photomicrograph of air-borne coal dust. A particle of dust is anything but a sphere, and the microscope only gives us information concerning the projection of the particle on a single plane ; the shape in the third dimension is not revealed. Frequently we see aggregates of particles, and these are clearly more difficult still to characterize by a " diameter " estimated from the microscopic appearance. It is necessary, therefore, to attempt to assess a characteristic of a particle, or an aggregate of particles, which bears a definite relationship to its motion in the free air or in the respiratory system. An appropriate measure is the aerodynamic or Stokes's diameter, which is the diameter of a sphere which falls in free air at the same rate as the particle ; we can either consider the sphere to be of unit density or of that of the material of the particle, if this be known. Alternatively we could define the size of a particle directly in terms of its Stokes's terminal velocity. For a spherical particle this is given by :—

$$V_s = \frac{d^2 \rho g}{18 \eta}\left(1 + \frac{AL}{d}\right) \quad . \quad . \quad . \quad . \quad (1)$$

where V_s = terminal velocity, d = diameter of sphere,

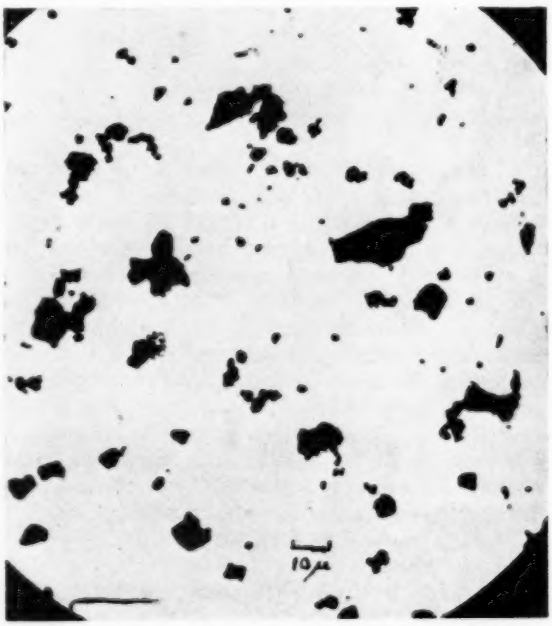

FIG. 2.—Photomicrograph of coal dust.

ρ = density of sphere less density of fluid through which sphere is falling, η = viscosity of fluid, g = acceleration due to gravity, A = a constant (about 1·6), L = mean free path of air molecules (about 10^{-5} cm.).

This equation holds for spheres of unit density up to about 80μ diameter. The function in brackets is the Cunningham correction for slip through the discontinuities of the medium and is only significant for small particles, being some 8% for spheres of diameter 2 μ. Apart from the term in the Cunningham correction, we see that the property of the sphere that determines its terminal velocity in air is very nearly the product of the square of the diameter and its density.

The passage of air from the nose to the depths of the lung and back again is extremely tortuous. Particles in this air will lag behind any change in direction and will tend to be thrown out by centrifugal force and by impingement, as well as to be deposited under the effect of gravity. For all these processes, it is the same parameter, viz. $d^2\rho$, that determines the degree and rate of removal. In other words, the terminal velocity of a sphere, or indeed of a particle or aggregate of any shape, is the parameter that determines its behaviour in penetrating the respiratory system. Only for spheres can we assess this parameter by direct measurement under the microscope.

Experimental Determination of Aerodynamic Diameter

We are faced, therefore, with the problem of determining the aerodynamic diameters of real dust particles. An attempt has been made to do this directly using a conifuge. This is an instrument devised by Sawyer and Walton (1950), in which an indrawn cloud is " winnowed " in such a way that the particles are classified according to their terminal velocities. Dust enters the apex of the annular space between a rotating solid cone and a similarly rotating outer conical sheath on to which the particles are precipitated by centrifugal force. Large particles are deposited close to the entrance of the instrument, successively smaller sizes being deposited further away from the sampling orifice. When particles are of similar shape and density, the settling velocity is a unique function of size, and the deposit is in the form of a spectrum of particle sizes with a high degree of purity. This may be demonstrated by examining the deposit from a cloud of spherical particles. At any one position in the spectrum the deposit will consist of particles with the same terminal velocity, irrespective of the density and shape of the particle or of the complexity of an aggregate.

Dusts were rendered air-borne in the laboratory and sampled with the conifuge. Similarly, small spheres of pyrex glass (ρ = 2·25 g./cc.) were sampled on the same slide as the dust particles. The mean projected diameter (d_p) of a large number of particles was measured, and corresponding to each dust particle the diameter of a neighbouring sphere on the deposit was also measured. Allowing for the respective densities of particle and sphere the value of the aerodynamic diameter, d_s, for each particle was calculated. Only discrete or unitary particles have so far been considered.

The conifuge has been used in this way to determine the ratio $d_p : d_s$ for a number of different dusts. Full details of this work will be published elsewhere and only the results obtained for coal-dusts and for china-clay and quartz are given here (Table 2). Measurements were made on particles

TABLE 2

RATIO OF MEAN PROJECTED DIAMETER TO AERODYNAMIC DIAMETER FOR A NUMBER OF COAL DUSTS AND FOR CHINA-CLAY AND QUARTZ DUST

Origin of Dust	Value of Mean d_p/d_s	Standard Error of Mean	No. of Particles Measured
S. Wales	1·35	0·015	128
Lancashire	1·31	0·013	124
Cumberland	1·35	0·012	147
China clay	1·61	0·016	134
Quartz	1·67	0·021	150

over a range of d_p of from 2 μ to 8 μ, and within this range there was no indication of any change in the ratio with particle size (Fig. 3).

Derivation of Standardized Lung-Deposition Curve

Measurements of the aerodynamic diameters were made for china-clay, because Brown and his colleagues used dust of this material for their lung-deposition experiments, in which they estimated particle size in terms of the Feret statistical diameter. Measurements were made of the ratio of the Feret diameter to the mean projected diameter for the sample of china clay dust examined, the mean value being found to be 1·15 (standard error 0·01). We can, using this ratio, correct the particle size of Fig. 1 to mean projected diameter, but the resulting curves will be appropriate only for china-clay dust, with particle size measured in terms of d_p, the mean projected diameter. Other dusts contain particles of different density and different mean d_p/d_s, and it is possible to construct curves for individual dusts. As an intermediate stage in the necessary computation, a standardized lung-deposition curve for spheres of unit density has been

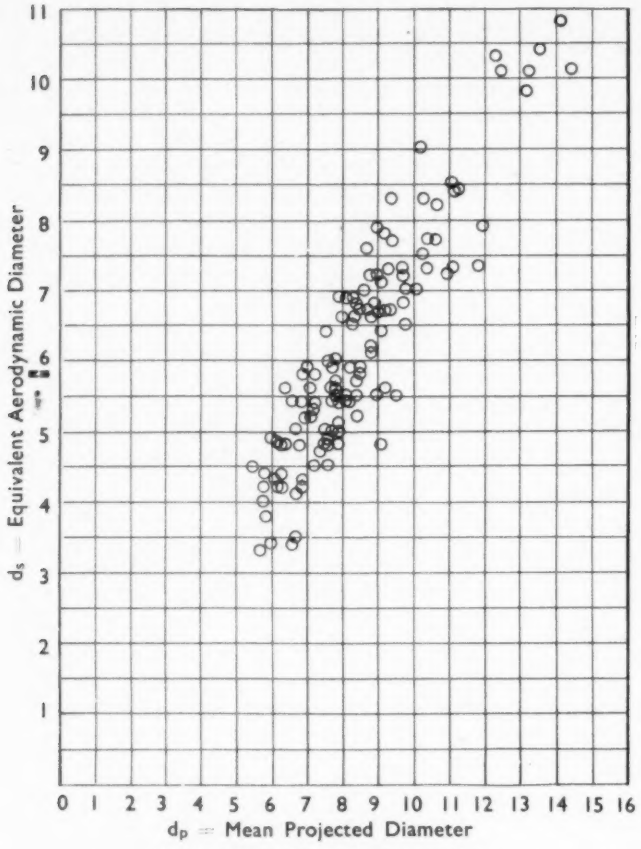

FIG. 3.—Plot of d_p v d_s for coal particles.

(Davies, 1949). It is mainly because the amended lower curve of Fig. 1 extrapolates smoothly to zero deposition at 12μ diameter that it has been selected in preference to the upper curve or any intermediate curve. The actual shape and position of the extrapolated part of the curve is of little importance for the argument developed in this paper. The absolute values of the ratios given in Table 4 are dependent somewhat on the manner of the extrapolation, but not so their relative values.

Using the standardized lung-deposition curve we can work in the reverse direction and draw up curves relating to any dust, for which the density and the mean d_p/d_s are known. Taking the density of coal to be 1·31 g./cc., the determined mean value for the samples examined and that of quartz to be 2·65 g./cc., Figs. 5 and 6 have been constructed for these two substances.

These lung-deposition curves can be used to estimate the fraction of a dust cloud that will be deposited in an arbitrary "standard lung" operating under the conditions of the experiments of Brown and others. The lung deposition curves can only be applied directly to calculations for aggregate-free dusts, but an aggregate will stand the same relative chance, depending on its aerodynamic diameter, constructed (Fig. 4). This has been derived from the lower curve of Fig. 1, the particle size scale having been amended by the following steps :—

(1) Divide given diameter scale by 1·15 to convert from Feret diameter to mean projected diameter; (2) divide by 1·61 the mean value of d_p/d_s for china-clay dust; (3) multiply by $\sqrt{2{\cdot}60}$, where 2·60 is the density of the china clay dust. This is done because the terminal velocity of a particle is proportional to the product of density and the diameter squared, and so the aerodynamic diameter of a sphere of unit density is larger than that of a particle of density ρ by a factor equal to the square root of ρ.

The derived curve of Fig. 4 has been smoothly extrapolated to zero deposition at 12μ diameter, the minimum size of sphere of unit density that is completely retained by the nose

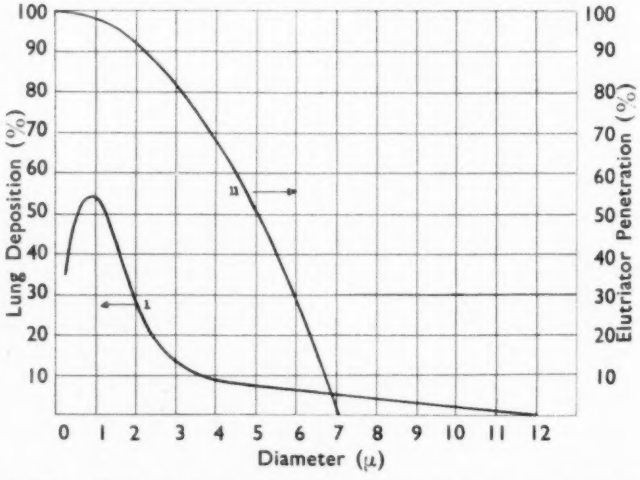

FIG. 4.—I. Standardized lung deposition curve for spheres of unit density.
II. Standard elutriator penetration curve for spheres of unit density.

of penetrating a selector device (see below) as an equivalent unitary particle or sphere.

Dust-Sampling Instruments and Lung Deposition Curves

We shall now consider the relationships between the performance of certain sampling instruments and the standardized lung deposition curve of Fig. 4, or of its derivatives, Figs. 5 and 6. An ideal instrument should reject everything larger than the aerodynamic equivalent of a 12 μ diameter sphere of unit density, and select smaller particles in proportions, depending on their sizes, as indicated by the curves. As any selector device in a real instrument will of necessity be much simpler in construction than the human respiratory system, it is likely that only an approximation to any chosen lung deposition curve will be obtained. We are, however, really concerned only with the relative shapes of the selector penetration and lung deposition curves, as absolute values may be adjusted as required by instrumental constants.

Four possible methods of selecting a respirable fraction of dust will be considered : (1) elutriation, (2) impaction, (3) centrifugal force (cyclone), (4) selective counting of a thermal precipitator or similar samples collected on cover glasses.

With all these methods, large particles may be trapped readily or ignored (Method 4). That fraction of the dust passing the selective device constitutes the sample representative of what is likely to be deposited in the lung. It must of course be collected in a suitable manner on a filter or a glass surface, for subsequent assessment in an appropriate way.

Elutriation.—Walton (1950) has shown that both for the conventional vertical elutriator and for a horizontal plate separator through which dusty air is passed particles will penetrate according to equation (2)

$$P = \left(1 - \frac{d_s^2}{d_o^2}\right) \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where P is the probability of a particle with aerodynamic diameter d_s passing and being collected as part of the sample, d_o being the aerodynamic diameter of the cut-off size, i.e., the size which just does not penetrate and which depends on the design of the apparatus. This property of separation has been suggested by Walton (1950) for the characteristics of an ideal sampling instrument, with 50% sampling, i.e., penetration through the separator, for spheres 5 μ diameter of unit density. The resulting curve is shown in Fig. 4, and may be compared with the standardized lung-retention curve derived from the experimental results of Brown and others (1950).

Impaction.—An impactor device could be designed to give the same type of selection, or one with an even sharper degree of separation. The practical difficulties of this particular approach are rather large and impactors will not be considered further.

Centrifugal Separation.—A small cyclone separator appears to allow a penetration of dust more closely resembling penetration to the alveoli than does an elutriator device. In particular, the curve relating penetration to particle size is concave upwards (Linden, 1949) similar to that of the main part of the lung-retention curve, whereas that for the elutriator is convex upwards. In Fig. 7 are given the results obtained on the penetration through a small cyclone of two different coal-dust clouds. The first was a cloud produced in the laboratory which contained very few aggregates, the second a

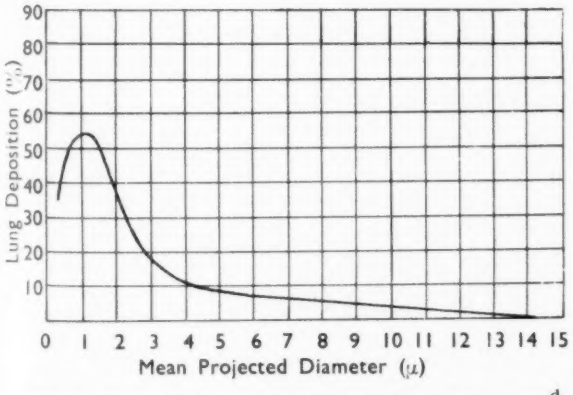

FIG. 5.—Standardized lung deposition curve for coal ($\rho = 1{\cdot}3\ \frac{d_p}{d_s} = 1{\cdot}35$).

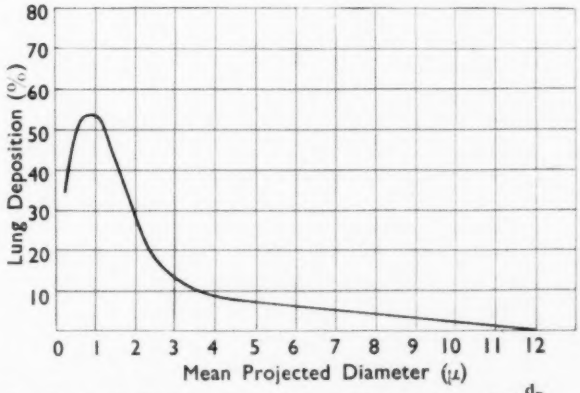

FIG. 6.—Standardized lung deposition curve for quartz ($\rho = 2{\cdot}65\ \frac{d_p}{d} = 1{\cdot}67$).

coal-mine cloud containing its usual quota of aggregates.

The two fractions of the dust, that retained by the cyclone and that passing which was collected on a suitable filter, were examined separately. Portions of each fraction were mounted in a dispersed state in Canada balsam and number size-distributions were made under a microscope. From these the corresponding mass-distributions were calculated, and knowing the relative masses of dust of all sizes retained in and passing the cyclone, the actual curve of retention against size was developed. The results for the two dusts are given in Fig. 7 in terms of mean projected diameter, together with the theoretical elutriator curve for coal (dotted line) also in terms of the mean projected diameter. These curves may be compared with the derived-lung deposition curve for coal (Fig. 5).

The two cyclone curves differ appreciably, and the reason probably lies in the different states of aggregation of the two dusts. The laboratory dust contained very few aggregates and the experimentally determined penetration curve corresponded well with that to be expected, with penetration tending to 100% for the smaller particles.

Aggregates present in the dusts would be broken down when representative fractions were mounted in Canada balsam for microscopical examination. In particular, small particles attached to larger ones would be stopped in the cyclone and so included in the retained fraction and seen and counted as small particles. Had such particles not been part of a relatively heavy aggregate, they would have penetrated. It has been thought that many aggregates are broken down in a cyclone, but the present results suggest that, on the contrary, further aggregation may take place.

The cyclone penetration curve No. 1, which is for the non-aggregated dust, and not curve No. 2, is suitable for direct comparison with the curves given in Figs. 4, 5, and 6.

Selective Counting.—The fourth possibility is to count over a restricted range of sizes the particles in a thermal precipitator or similar quantitative sample. This will be the equivalent of a sharp cut-off at the top and at the bottom of the selected range, 100% of the particles within the range being counted. In so far as the aerodynamic diameter of a particle and particularly that of an aggregate cannot be estimated directly by microscopical examination, this approach is not likely to be as satisfactory as the two others that have been discussed in some detail, which collect or reject an aggregate according to its aerodynamic diameter in the manner indicated by the appropriate curves. There are also errors involved in deciding under the microscope the correct d_p of an irregularly shaped particle, and thus whether or not to include or exclude these particles near the chosen limits of size. Apart from this, microscopic assessment of dust is a tedious matter, and it can be argued that particle number concentration is not likely to be as good an index of hazard as area or mass concentration within the respirable range of size. On the other hand, if a selective device is used with a thermal precipitator, there are two possibilities of assessing quickly the resulting sample. One is to obtain a measure of the surface area of the dust by means of a photoelectric densitometer. The other is to count the deposit electronically using a suitable scanning device; developments on this line are reported by Walton (1952).

Performance of Selector Devices Compared with Lung.—The alveolar deposition of a number of dusts has been calculated in terms of particle number, surface, area, and mass, using the appropriate derived lung-deposition curves. In addition, for comparison, the penetration through two instruments, an elutriator or horizontal separator and the small cyclone (Dust 1), have also been calculated. To make results comparable, the lung depositions and instrument penetrations have been calculated in each case for 100 particles of the various dusts,

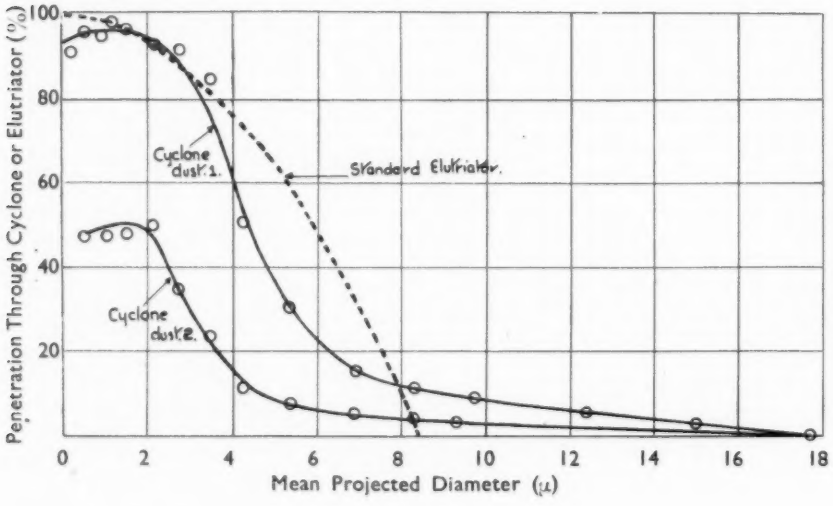

FIG. 7.—Dust penetration through small cyclone separator compared with theoretical penetration through standard elutriator (coal dust).

counts being made down to about 0·2 μ with a 2 mm. objective. Details of the dust examined are given in Table 3.

TABLE 3

NATURE AND SIZE-DISTRIBUTION OF DUSTS USED FOR CALCULATION OF LUNG DEPOSITION AND OF SELECTOR DEVICE PENETRATION

Dust	Dust Code No.	Sampling Method	% Occurrence by Number in Size-range (mean projected diameter in μ)			
			<0·5	0·5–2	2–5	>5
Coal-mine dusts						
S. Wales	A (i)*	Filter	13	38	39	10
S. Wales	A (ii)	,,	7	45	37	11
Cumberland ..	A (iii)	,,	2	40	48	20
Lancashire	A (iv)	,,	1	31	52	16
S. Wales	B (i)	T.P.	18	32	34	16
Cumberland ..	B (ii)	,,	29	34	27	10
Cumberland ..	B (iii)	,,	44	26	20	10
Cumberland ..	B (iv)	,,	23	33	30	14
Rock dusts						
K.G.F. dry drilling†	C (i)	T.P.	37	51	10	2
K.G.F. wet ,,	C (ii)	,,	47	43	8	2
S.A. dry drilling‡ ..	D (i)	,,	16	43	26	15
S.A. wet ,, ..	D (ii)	,,	82	13	4	1

*Samples in group (A) were taken with a gravimetric sampler (Watson and Morris, 1952). Portions of these dusts were dispersed in Canada balsam for size distributions to be made. Thus, aggregates were broken down, in contrast with the assessment of the T.P. samples for which aggregates were counted and sized as single particles. †K.G.F. = samples taken in the mines of the Kolar Gold Field in India (Watson 1952). ‡S.A. = samples taken in the gold-mines of South Africa (Patterson, 1939–40). Three of the filter samples appear to be deficient in small particles. This is probably a function of the mounting technique. For the purpose of the present argument the distorted size-distributions thus obtained are of value in that they extend the range considered.

The first point to note concerning these various dusts is that they cover a very wide range of size distributions, in both the coal and the rock dust series. The two series contain dusts of different densities, approximately 1·3 g /cc. for the coal dusts and approximately 2·65 for the rock dusts.

For 100 particles of each dust, values of the following functions have been calculated :—

$$\left.\begin{array}{ll} \text{For number} & \Sigma\,(n.r) \\ \text{For area} & \Sigma\,(nd^2.r) \\ \text{For volume} & \Sigma\,(nd^3.r) \end{array}\right\} \quad \text{Equation (3)}$$

where n is the number of particles in a small size group of mean diameter d, and r is the fractional lung deposition or selector device penetration at this mean size. In all these calculations the mean projected diameter has been used as a measure of particle size, the curves for the selector device and for lung deposition being appropriate to the density and value of d_p/d_s of the dust.

In Table 4 are given the ratios of the values of those functions for number, area, and mass (or volume) for (1) penetration through standard elutriator or horizontal separation to lung deposition, and (2) penetration through cyclone (Dust 1) to lung deposition.

TABLE 4

CALCULATED VALUE OF RATIOS OF PENETRATION THROUGH SEPARATING INSTRUMENTS TO LUNG DEPOSITION FOR A NUMBER OF DUSTS IN TERM OF NUMBER, SURFACE AREA, AND MASS

Dust Code No.	Penetration through Elutriator			Penetration through Cyclone		
	Lung Deposition			Lung Deposition		
	Number	Area	Mass	Number	Area	Mass
A (i)	2·79	4·16	3·75	2·72	3·62	3·37
(ii)	2·43	3·42	3·00	2·38	3·60	3·42
(iii)	2·98	4·26	3·73	2·37	3·10	3·06
(iv)	2·46	4·10	4·06	2·84	3·55	3·27
B (i)	2·84	4·30	3·99	2·66	3·44	3·32
(ii)	2·72	4·11	4·02	2·57	3·16	3·32
(iii)	2·75	4·18	4·05	2·57	3·38	3·36
(iv)	2·77	4·04	3·62	2·59	3·33	3·14
C (i)	2·88	3·33	3·96	2·19	2·92	3·30
(ii)	2·32	3·30	3·89	2·21	2·87	3·17
D (i)	2·56	3·68	3·19	2·42	3·35	3·47
(ii)	2·52	3·61	3·57	2·38	2·75	2·55
Means	2·62	3·87	3·74	2·49	3·26	3·23
S.D.	0·22	0·379	0·344	0·20	0·294	0·244

It must be pointed out that many simplifying assumptions have been made in producing the figures in Table 4. The main ones are that the experimental results given by Brown and others (1950) are reliable. The china clay dust used by Brown and others was similar in physical characteristics to the sample examined to determine the shape factors used to standardize the experimental lung deposition curve. The statistical values of the ratios d_p to d_s for coal and quartz are reliable. The limiting size of particles that can reach the alveoli is correct, i.e., a sphere of unit density and 12 μ diameter. In making the calculations for the elutriator it has been assumed that the theoretical relationship of Equation (2) is achieved in practice.

The results of Table 4 give some of the properties of selectors in comparison with the lung deposition curves. For example, in comparison with the standardized lung deposition of a dust cloud, the amount calculated to pass either of the selectors, and hence collected as the sample, is comparatively insensitive to particle size distribution, shape, or density. The relative amount of dust calculated to pass the selector of either kind is similar in terms of number, area, and mass respectively. For comparative assessment of the physical concentration of the respirable fraction of a dust, either selector considered would be suitable, irrespective of the unit of concentration. An absolute measure could be derived by dividing the practical value by the

appropriate mean ratio given at the foot of Table 4. More dust is actually included in the sample than would be deposited in the lung when breathing at the same minute volume as the sampling rate. As the size-distribution of the dust passing either selector is not the same as that reaching the lung the chemical and petrological composition of the actual sample may be a little different from the dust actually reaching the lung, when there is a marked change in composition with particle size. Thus it should be possible to use with confidence selective sampling devices to simulate the human lung. The best units in which to express dust concentration is a matter for further investigation, but there are advantages in deciding on mass, for it is easily determined with precision using standard apparatus. For comparative results to be obtained in different situations it is necessary, however, to standardize the design of sampling apparatus. Further, it is important that the sampling rate be held constant at the designed value, using, for instance, a critical orifice. For, if it changes, the particle-size/selection curve changes too, and the error in the amount of sample collected will be about double what it would be without the selector device.

Naturally, the above refers to a "standard" lung. The actual amount of dust deposited in any instance will depend on breathing rate and breathing pattern (Davies, 1952).

Summary

An examination is made of the possibilities of designing a dust-sampling instrument to give directly an index of concentration proportional to the amount of dust likely to be deposited in the lung. Such deposition will depend, among other things, on the size-distribution of the dust particles in the cloud being breathed, and on their density and shape. The aerodynamic diameter of a particle is the correct measure of its size in this context, and results are given for a number of dusts of the relation between this and the mean projected diameter as determined with a microscope.

Lung deposition *versus* particle size curves are derived for a number of natural dusts. These are compared with the curves of penetration of dust through some selector devices which trap the larger particles, leaving the smaller ones to pass through to constitute the sample.

The results obtained suggest strongly that it is possible to use with confidence selective sampling devices which satisfactorily simulate the upper passages of the human respiratory system, and will allow to pass to a suitable depositing element a sample from which can be derived directly a measure of the concentration of the respirable fraction of a dust. This sample will give a comparable index of concentration which is almost independent of the dust, its size-distribution, density, and particle shape.

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PNEUMOCONIOSIS OF COAL MINERS IN SCOTLAND

BY

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There is ample evidence to prove that pneumoconiosis occurs among coal miners in all the British coalfields but so far detailed information has been almost entirely restricted to South Wales and to a recent study by McCallum (1952) in North-East England.

This paper presents some recent experience of the disease among coal miners in Scotland based on the records of the Pneumoconiosis Medical Panel (previously the Medical Board for Silicosis and Asbestosis) of the Ministry of National Insurance. The records were compiled from examinations made between 1944 and 1949 of persons claiming benefit for disablement due to pneumoconiosis.

Mine dust is a complex mixture of minerals derived from the disintegration of the coal and the rocks in which it occurs. As these minerals are not uniform in composition throughout the coal measures of Great Britain, miners may be exposed to the inhalation of dust of varying composition. This fact alone may have an important influence in determining the incidence and type of pneumoconiosis among workmen in different mining occupations and areas.

Geography and Geology of the Scottish Coalfields

Practically all the workable coals in Scotland occur in the carboniferous formation within the Midland Valley (central Scotland) and in the Sanquhar-Kirkconnel basin in Dumfriesshire. Small areas of workable coals are found at Machrihanish in the Canonbie district on the Solway Firth and at Brora in Sutherlandshire, but as no cases of pneumoconiosis from these detached areas have arisen in the present series they will not be considered (Scottish Home Department, 1944).

The coalfields of Scotland have been grouped into broad divisions in Fig. 1. Their subdivisions are described in an appendix.

All the workable coals in the Scottish coalfields occur in the carboniferous formation, the subdivisions of which from surface level downwards are as follows :—

Coal measures
- (a) Barren red measures
- (b) Productive coal measures

Millstone grit

Carboniferous limestone series
- (a) Upper limestone group
- (b) Limestone coal group
- (c) Lower limestone group

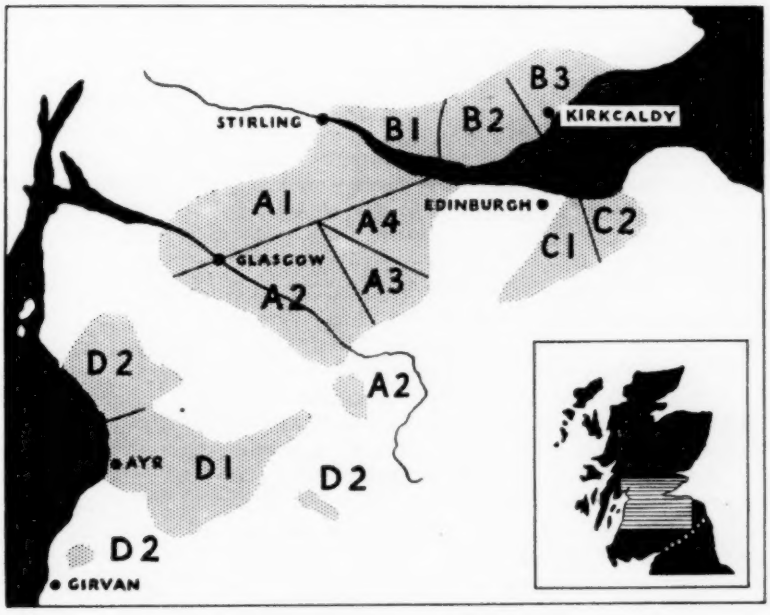

FIG. 1.—The coalfields of Scotland.

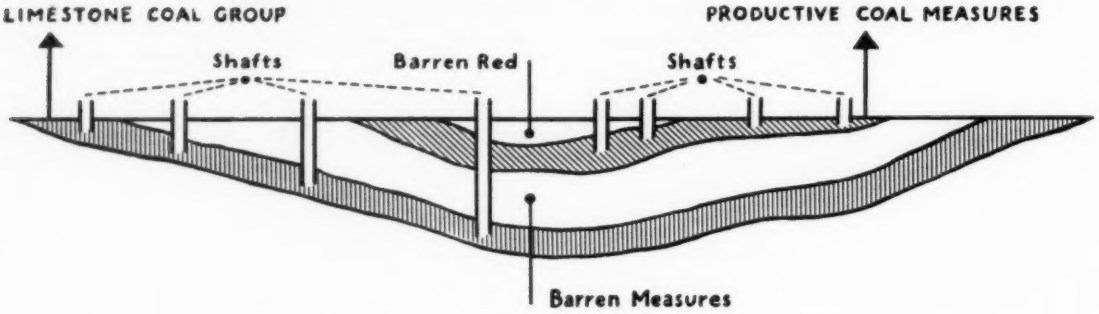

FIG. 2.—Diagram of the valuable seams of coal and of the barren measures.

The valuable seams of coal occur in the productive coal measures and in the limestone coal group. Any coals in the intervening strata, that is in the millstone grit and upper limestone group, are not worked and are designated barren measures (Fig. 2). Some of the coalfields and areas contain both series of coal-bearing rocks. In some districts the workable seams lie at shallow depths while in others they have to be worked at much greater depths.

No significant geological differences in rock formation would be encountered in extracting coal from the productive coal measures and the limestone coal group (Macgregor, personal communication). But in certain districts and collieries and even in different seams in the same colliery, work in thin seams, necessitating brushing the roof or pavement, and faults requiring more mine driving to follow the seams of coal, may add considerably to the silica content of the dust.

Definitions

Since 1928 when legislative provision was first made for the payment of compensation to coal miners disabled by silicosis there have been several changes in the law (Sutherland, 1949). But in the present study the disease was recognized as pneumoconiosis as defined in the Coal Mining Industry (Pneumoconiosis) Compensation Scheme, 1943, namely, " fibrosis of the lungs due to silica dust . . . or other dust and includes the condition of the lungs known as dust reticulation ". As the review relates to the years 1944–49 this, in effect, means all applications from coal miners made in pursuance of the above scheme, or the National Insurance (Industrial Injuries) Act, 1946. There are differences in procedure between these two enactments, but from the medical point of view the definition of the disease is the same and disablement arising from the disease can be recorded on a similar basis. In assessing disablement the effects of tuberculosis accompanying pneumoconiosis are reckoned as those of pneumoconiosis.

It was also necessary to ensure that all men included in the survey could rightly be assigned to coal mining in the Scottish Area. The records showed that in the specified six-year period 1,953 claimants were examined by the Medical Panel under the two schemes named above. Thirty-nine men who made claims had had substantial exposure to dust outside the coal mining industry in such occupations as stone-quarrying, foundry work, and shale mining, or had been employed for considerable periods in coal mines outside Scotland. They have been excluded from this study, thus reducing the total to 1,914 persons, of whom 1,315 were certified to be suffering from pneumoconiosis. While some of these had been employed temporarily in surface occupations all had engaged mainly in underground work.

During the period some workmen had two or more examinations, either because of a previous refusal by the Medical Panel to grant a certificate or for reassessment of the degree of disability. These cases were allocated to the year in which a certificate was granted.

The numbers of certifications are shown in Table 1.

TABLE 1
CERTIFICATIONS BY YEAR AND COALFIELD

Year	Scottish Area	Coalfield			
		A	B	C	D
1944	76	40	15	9	12
1945	125	75	17	20	13
1946	154	96	24	26	8
1947	292	196	31	39	26
1948	289	171	48	38	32
1949	379	245	44	47	43
1944–1949	1,315	823	179	179	134

During this period there has been a considerable and progressive increase in the number of men certified in all four main coalfields. This increase, however, is not uniform throughout the coalfields, for, whereas the increase in A is six times and in C is five times, in B and D the increases are threefold.

As explained, these cases represent only those dealt with under the Coal Mining Industry (Pneumoconiosis) Compensation Scheme, 1943, and the National Insurance (Industrial Injuries) Act, 1946. However, there were a number of additional certifications arising out of previous schemes.

TABLE 2
ALL CERTIFICATIONS FOR THE SCOTTISH AREA FOR 1939 TO 1949

Year	1939	1940	1941	1942	1943		1939–43
Number of certifications	7	2	3	6	10[a]		28
Year	1944	1945	1946	1947	1948	1949	1944–49
Number of certifications	109	148	166	322	317	419	1,481

[a] for 1943 represents cases of silicotic type.

Table 2 shows all certifications for the years 1939–49. In the Various Industries (Silicosis) Scheme, 1931, the definition of silicosis was considerably narrower than that of pneumoconiosis given above, and in the Pneumoconiosis (Benefit) Scheme, 1943, it was required that the claimant should be totally disabled by pneumoconiosis.

Since the Coal Mining Industry (Pneumoconiosis) Compensation Scheme became effective on July 1, 1943, this year may be accepted as a natural division. Accordingly the above figures reveal that the mean annual number of certifications for the five years 1939–43 was 5·6, whereas for the six years 1944–49 it was 247, an increase of 44 times. According to Fletcher (1948) the mean annual number of certificates of South Wales coal miners since 1942 up to and including 1946 has risen to four or five times the rate in 1942. From our data the corresponding increase in the Scottish area in the same years is 18 times. The increase in Scotland started suddenly in 1944 and has continued since. It is of interest and importance to consider the possible reasons for this increase.

With the introduction of the Coal Mining Industry (Pneumoconiosis) Compensation Scheme, 1943, and the prescription of dust reticulation an almost immediate increase was to be expected. In other words, many workmen suffering from disabling chronic pulmonary disease due to dust but not amounting to silicosis, who, before 1943 would have failed to obtain a certificate, now succeeded because of the wider definition of the disease. Few new applications arose in the first six months of the scheme, possibly due to the fact that workmen and doctors required some time to become fully aware of the new legislation.

Also, in order that a workman should be enabled to benefit under the new scheme, it was necessary that he should have been employed in or about a coal mine on or after July 1, 1943. The National Insurance (Industrial Injuries) Act, 1946, further facilitated applications by remitting all fees payable by the claimant and by rescinding the provisions as to compulsory suspension from work on certification except in cases in which the pneumoconiosis was accompanied by tuberculosis. Furthermore, the payment of disablement benefit was not conditional as hitherto on loss of earnings.

That the increase was not entirely due to the inclusion of dust reticulation is suggested by taking account of cases occurring in the years 1944–49, in which (Table 3) the radiographic appearances

TABLE 3
CASES OF SILICOTIC TYPE

Certification in Pursuance of . .	1944	1945	1946	1947	1948	1949	1944–49
V.I.(S) S 1931 . .	10	13	6	27	8	12	76
P (B) S 1943	4	3	4	6	4	2	23
CMI (P) CS 1943 } N.I.(I.I.)A.1946) }	30	48	68	90	92	92	420
Total (all schemes) . .	44	64	78	123	104	106	519

V.I.(S) S 1931 = Various Industries (Silicosis) Scheme, 1931. P (B) S 1943 = Pneumoconiosis (Benefit) Scheme, 1943. CMI (P) CS 1943 = Coal Mining Industry (Pneumoconiosis) Compensation Scheme, 1943. N.I.(I.I.) A. 1946 = National Insurance (Industrial Injuries) Act, 1946.

revealed changes more advanced than dust reticulation and which, under any of the compensation schemes relating to coal miners, would have been interpreted and certified as silicosis.

This represents a mean annual number of certifications by reason of silicosis of 86·5 for the years 1944–49 as against 4 8 for the years 1939 to 1943 (see Table 2), which is an increase of 18 times. Thus it would appear that 519, or 35%, of the 1,481 total certifications under all schemes among coal miners in Scotland in the years 1944–49 can be accounted for by patients with silicosis to whom a certificate would have been granted even if the legislation had not been extended to include dust reticulation. This is if anything an underestimate, as doubtful or borderline cases have not been included.

Certain factors which, by stimulating applications, may have given rise to an apparent increase in the

frequency of the disease should be mentioned. There is no doubt that a number of older miners and others whose physical capacity for work was impaired patriotically carried on during the war. Subsequently they began to leave the mines and made application for certificates of disablement. Again the exhaustion of coal workings, for example in central Lanarkshire, led to some pits being closed with the result that men in impaired health who were able to continue working in their own pits found the effort of starting off in a new district beyond their capacity. This had the effect of bringing such cases forward for certification. Then, during the last few years facilities for radiological examination of the chest at hospitals and in mass radiography surveys had greatly extended and was the means of discovering some unsuspected cases of the disease.

However, even when due allowance is made for these influences it seems reasonable to suggest that there has been a true increase in the occurrence of pneumoconiosis in the Scottish coalfields during recent years. As has been shown above, a definite rise in the number of certifications showing the silicotic type of disease has taken place. Moreover, as on first examination by the Medical Panel about one-half of all these persons was judged to be totally disabled and the remainder showed definite impairment of physical capacity for work, it is probable that the application for a certificate was determined by illness and not by any accidental discovery.

Incidence of Pneumoconiosis

Fletcher and Oldham (1949) have emphasized the errors of interpretation which occur in the radiological diagnosis of pneumoconiosis, and Cochrane (1951) has discussed the disparity between certification rates and true prevalence rates simply because affected men may continue to work without seeking examination. With these two sources of error the certification rate cannot reflect the true incidence of the disease. But over a number of years, other factors remaining constant, it should be an index of *disabling* disease. (Certification rate is here used to mean the annual number of certifications per 1,000 underground workers.) The rates are based on populations underground in 1944. It is assumed that these populations did not change substantially during the period under review (Table 4). For the whole of Scotland the rate rises from 1·21 in 1944 to 6·06 in 1949 with a mean annual rate for the years 1944–49 of 3·50. When the total number of certifications under all schemes is taken into consideration the corresponding figures are 1·74, 6·69, and 3·95 respectively.

TABLE 4

MEAN ANNUAL CERTIFICATION RATES PER 1,000 UNDERGROUND WORKERS IN THE SEPARATE SCOTTISH COALFIELDS AND SUBDIVISIONS

Coalfield or District	Underground Workers	Number of Certificates	Certificate Rate Mean 1944–1949
Scotland ..	62,553	1,315	3·50
A	29,744	823	4·61
A1 ..	8,646	119	2·29
A2 ..	10,889	319	4·88
A3 ..	4,624	273	9·84
A4 ..	5,585	112	3·34
B	15,251	179	1·96
B1 ..	2,582	32	2·06
B2 ..	7,589	121	2·66
B3 ..	5,080	26	0·85
C	7,999	179	3·73
C1 ..	5,226	77	2·44
C2 ..	2,773	102	6·13
D ..	9,559	134	2·34
D1 ..	7,456	91	2·03
D2 ..	2,103	43	3·41

A considerable variation in the mean annual certification rate for the years 1944–49 is found between the separate coalfields ranging from 4·61 in A to 1·96 in B.

If these figures are further broken down into districts within the separate coalfields the variation in certification rates is even more striking. Districts A3 and C2 have high certification rates of 9·84 and 6·13 respectively and B3 the lowest rate of 0·85. The possible causes for these large differences must be considered.

Geological Formation.—Area B3 and coalfield D are essentially productive coal measures, yet the mean annual certification rates differ as between 0·85 and 2·34. Similarly in areas A1, B2, and C2, which are essentially of the limestone coal group, the respective rates are 2·29, 2·66, and 6·13. Then comparing coalfield D, which is 93·2% productive coal measures, with area A1, which is 92·5% limestone coal group, and both involving comparable numbers of workmen, the certification rates are almost identical, 2·34 and 2·29 respectively. The workmen with few exceptions had spent the whole of their working lives in a single area and so the incidence of disease should reflect the dust hazards of the coal measures of that area.

Thus it seems that geological formation does not play any material part in the varying incidence of pneumoconiosis in the different areas of the Scottish coalfields. This is in keeping with the information recorded earlier that there are no significant geological differences between the productive coal measures

and the limestone coal group such as would result in any material differences in the quality of airborne dust to which these separate groups of miners are exposed.

Dustiness of Mines.—Sir Andrew Bryan (1949, 1950) H.M. Chief Inspector of Mines, has emphasized the important part played by the increased production of dust which has resulted from greater mechanization in mines. But mechanization itself is not the only factor affecting the production of dust. Jenkins (1948) states that the progress of mechanization in the South Wales coalfield, where the incidence of certified cases far exceeds that of all other areas (Fletcher, 1948), has proceeded much more slowly than in other parts of Great Britain. He attributes the high incidence of pneumoconiosis in South Wales coal miners to the dry, dusty conditions prevailing there.

Other factors which probably affect the dustiness of a mine are thinness of the seams and frequent faulting, conditions which are more common in some areas than in others. Not only do they affect the quantity of airborne dust but they alter the quality by increasing the silica content.

With regard to mechanization and the nature of workings, Dr. C. G. Gooding, Divisional Medical Officer, National Coal Board, Scottish Division, gives the following information, some of which has been published in the Ministry of Fuel and Power Statistical Digests for the years 1945–49.

Mechanization.—In 1913 only 8% of coal in Great Britain was machine-cut. At this date the corresponding figure for Scotland was 22% and most of this was in thin seams in the Lanarkshire coalfield. Indeed, Lanarkshire is reputed to be the home of the coal-cutter. During the ensuing 15 years there was a general expansion but the relative positions recorded above were more or less maintained.

Conveyors of bigger capacity were brought into use while machine cutting was extended to thicker seams. In 1928 12% of coal in Great Britain was mechanically conveyed ; in Scotland 25%. Machine cutting was, until about 1930, much more general in Lanarkshire, and in the early years the disc cutter was in common use. It is said that about 30 years ago it used to be asked by miners in Muirkirk (Ayrshire), "Who is going to Shotts, to be poisoned?" This apparently referred to the fact that men returning from Shotts, where the disc cutter was used, were noted to be short of breath when they got back to Muirkirk, where the coal was hand-got by stoop and room methods.

Table 5, setting out the percentage of machine-cut coal, emphasizes that the mechanical cutting of coal in Lanarkshire and Fife and Clackmannan is substantially higher than in the other Scottish coalfields and in the rest of Great Britain. Nevertheless the certification rates do not appear to be parallel to the degree of mechanization, for whereas the certification rate in coalfield A (Lanarkshire) is 4·61, that in coalfield B (Fife and Clackmannan) is 1·96. On the other hand in the less mechanized coalfields the certification rates are intermediate between these. This would support the suggestion that mechanization *per se* is not the only factor in determining the certification rate in individual areas.

Other factors which can influence the incidence of pneumoconiosis are the awareness of miners and their medical attendants of the disease and of the legislative provisions for its compensation and of the age distribution of the workers at risk. It is not possible to assess the effect of the latter, but the officials of the National Union of Mine Workers are of the opinion that in all districts in Scotland there is a general awareness of the procedure with regard to claims.

Pneumoconiosis in Individual Collieries

An attempt was made to elucidate this point by scrutinizing the occupational histories of the 1,315 certified cases. Before any certified case was allocated to a particular colliery it was required that certain conditions should be fulfilled : (1) that all the colliery work had been carried out at one colliery ; or (2) that 30 years or more of the latest exposure had been at one colliery ; or (3) if employment amounted to less than 30 years that the latest exposure at one colliery had amounted to at least

TABLE 5

PERCENTAGE OF MACHINE-CUT COAL PRODUCTION

District	Year									
	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947
Fife and Clackmannan	90	89	91	91	91	92	93	92	93	92
Lothians—Mid and East	62	65	65	65	68	66	69	72	74	74
Lanarkshire	84	84	84	86	85	85	90	89	88	90
Ayr and Dumfries	69	70	70	72	72	74	74	77	76	72
Great Britain	59	61	64	66	66	69	72	72	74	75

75% of the total exposure, with a minimum of 20 years.

The Coalfields Report (1944) lists 221 collieries in the Scottish area and from these during the six years 1944–49 1,315 workmen were granted certificates. Only 166 workmen fulfilled the criteria defined for attachment to an individual colliery and these were derived from no less than 75 collieries.

It was found that of 39 collieries each had only one certified case which could reasonably be attributed to work in them; 12 collieries had more than three cases but one had 12 cases. Altogether only three collieries had more than an average of one certified case per annum. The numbers of underground workers at these three collieries were 214, 347, and 666, and the certifications over the six years numbered seven, nine, and 12 respectively. This emphasizes how difficult it is to use certification figures to determine the relative risks of separate pits.

Age and Years of Employment

The age here is taken as that at the date of first certification. No attempt is made to estimate the relative incidence of the disease in different age groups as this would involve knowledge of the population at risk at these ages, a matter on which no data are available for the period surveyed.

Only 2·4% of certifications occur under the age of 41 years (Table 6). Disabling disease occurs almost entirely in middle life or later. Most of the men had spent their whole working lives from the age of 14 years and even earlier in the mines, although for some the period had been interrupted by service in H.M. Forces during the first world war. A few had worked for short periods in non-mining occupations. In computing the period of employment in mining these extraneous occupations have been excluded. Table 6 also indicates that the disease is seldom manifest under 21 years of coal-mining employment.

TABLE 6
CERTIFICATIONS BY AGE GROUP AND PERIOD OF EMPLOYMENT

Age Group	Certifications		Years of Employment	Certifications	
	No.	%		No.	%
30 and under	0	0·0	20 and under	6	0·5
31–40	30	2·4	21–30	184	14·0
41–50	299	22·7	31–40	513	39·0
51–60	553	42·0	41–50	421	32·0
61 and over ..	433	33·0	51 and over	191	14·5
All ages ..	1,315	100·0	Total	1,315	100·0

The percentage of certifications after the age of 60 years in coalfields A (35·5) and D (40·3) is greater than in coalfields B (25·2) and C (23·5). If the individual years are considered a definite trend is apparent. The number of certifications and the percentage of each year's total has steadily advanced in the older age group, ranging among men over the age of 60 years from 11 or 14·7% in 1944 to 152 or 39·9% in 1949. Coalfields A and D have a definitely higher percentage of the total certifications in this advanced group than have coalfields B and C. Lanarkshire (A) and Ayrshire (D) are the oldest coal-mining areas and in recent years there has been a considerable decline of mining in the former. Closing the pits has displaced miners, many of whom felt disinclined and indeed were unfit for work elsewhere.

Type of Pneumoconiosis

Davies and Mann (1949) devised a radiological classification in which simple pneumoconiosis and complicated pneumoconiosis are recognized as the two main types of the disease In simple pneumoconiosis the *x*-ray appearances are considered to represent actual dust accumulation in the lungs together with localized foci of fibrosis, reticulation, and nodulation. In complicated pneumoconiosis the *x*-ray appearances are considered to represent dust accumulation and massive fibrosis due to the action of dust alone or in association with tuberculous infection. Evidence has been adduced by Fletcher (1948) and Gough (1949) to show that complicated pneumoconiosis appears only as a result of associated infection, probably tuberculous, in lungs already occupied by dust. Moreover, Fletcher (1950), as a result of a series of researches, has concluded that massive fibrosis develops only on a basis of antecedent simple pneumoconiosis of category 2 or more.

Our personal experience is that radiological appearances of pneumoconiosis among coal miners in Scotland conform closely to those described by Davies and Mann in South Wales coal miners. Accordingly in this discussion simple pneumoconiosis and complicated pneumoconiosis bear the meaning attached to them by these authors.

Of the 1,315 certified cases, 358 or 27·2% were diagnosed as complicated pneumoconiosis (Table 7).

Table 7 shows that throughout the six years 1944 to 1949 there has been a definite increase in the absolute number of certificates given for complicated pneumoconioiss, but simultaneously the proportion of the latter in all certifications in each

TABLE 7
TOTAL DISABLEMENT AND COMPLICATED PNEUMOCONIOSIS IN SEPARATE YEARS

Year	Certifications	Total Disablement		Complicated Pneumoconiosis	
		No.	%	No.	%
1944	76	27	35·5	27	35·5
1945	125	31	24·8	37	30·0
1946	154	45	29·2	62	40·0
1947	292	75	25·7	78	26,7
1948	289	64	22·2	74	25·6
1949	379	63	16·2	80	21·1
1944–49	1,315	305	23·2	358	27·2

year has decreased substantially from 35·5 in 1944 to 21·1 in 1949. The proportion of all certificates for total disablement has declined in like manner. Complicated pneumoconiosis does not necessarily involve total disablement, and the double trend noted above would suggest that claimants are coming forward more readily at an earlier stage of the disease and before they are wholly incapacitated for work. This was to be expected, especially after July 5, 1948, as certification did not necessarily involve suspension from work and disablement benefit was payable without regard to earnings.

Disablement in Relation to Age

Table 8 shows that the degree of disability found at the time of first certification increases with the age of the applicant, a relationship which accords with the findings reported by Gilson (1951) in South Wales. This does not mean that age is the only factor involved in determining disability, for when the type of pneumoconiosis is related to the age of the applicant (Table 9) it appears that the percentage incidence of complicated pneumoconiosis progressively rises with age. This suggests that the

TABLE 8
CERTIFICATIONS BY DEGREE OF DISABILITY IN SEPARATE AGE GROUPS

Age Groups	Total	Total Disablement		Partial Disablement		No Disablement		All (%)
		No.	%	No.	%	No.	%	
30 and under	0	0	0·0	0	0·0	0	0·0	100·0
31–40 ..	30	4	13·3	16	53·3	10	33·3	100·0
41–50 ..	299	28	9·4	234	78·3	37	12·4	100·0
51–60 ..	553	107	19·4	424	76·6	22	3·9	100·0
61 and over..	433	166	38·3	259	59·8	8	1·8	100·0
All ages ..	1,315	305	23·2	933	71·0	77	6·0	100·0

TABLE 9
TYPE OF PNEUMOCONIOSIS IN RELATION TO AGE

Age Group	Certifications	Complicated Pneumoconiosis	
		No.	% of Age Group
30 and under	0	0	0·0
31–40 ..	30	4	13·3
	30	4	13·3
41–50 ..	299	49	16·4
51–60 ..	553	146	26·4
	852	195	22·9
61 and over ..	433	159	36·7
All ages ..	1,315	358	27·2

period of exposure to risk, which is reflected by age, may be a factor in the production of complicated pneumoconiosis.

Pneumoconiosis in Separate Mining Occupations

A number of applicants had been engaged in one type of work long enough to suggest that any pneumoconiotic changes present were probably due to a particular occupation. Four groups were defined, namely, brusher and stoneminer (261), fireman and shotfirer (35), machineman (79), hewer and stripper (187); the remaining 753 had had mixed employment. Although the attack rate of pneumoconiosis in the various groups cannot be calculated, the type of disease found in these occupational groups is of interest (Table 10). Among brushers and stoneminers, that is men whose work is predominantly in stone, the incidence of complicated pneumoconiosis not only increases with age, but is relatively more common at all ages than in the other occupational groups. Thus working in stone may be a further factor in the causation of complicated pneumoconiosis.

Massive fibrosis or complicated pneumoconiosis is a more advanced pathological state than simple pneumoconiosis. In general the more advanced the degree and type of the disease the more advanced the degree of disablement, but Table 11 shows that simple pneumoconiosis may cause total disablement and complicated pneumoconiosis may still be consistent with considerable working capacity.

Complicated pneumoconiosis has in every case been assessed as causing some degree of disablement. Fifty per cent. of the 358 persons suffering from it were certified to be totally disabled; the corresponding figure in respect of the 957 cases of simple pneumoconiosis was only 13·2%.

So far, then, the evidence suggests that the period at risk as reflected by age is a factor in the aetiology of massive fibrosis or complicated pneumoconiosis. In individual occupations stone work may be another contributory factor. Throughout the literature reference is always made to the influence of

TABLE 10
TYPE OF PNEUMOCONIOSIS IN OCCUPATIONAL GROUPS

Age Group	Brusher and Stoneminer		Fireman and Shotfirer		Machineman		Hewer and Stripper		Others	
	Cert.	% C.P.	Cert.	% C.P.	Cert.	% C.P.	Cert.	% C.P.	Cert.	% C.P.
50 and under ..	60	23·3	0	0·0	27	15·0	45	13·3	197	14·7
51–60	111	36·0	11	27·3	38	28·9	89	19·1	304	25·0
61 and over	90	45·5	24	25·0	14	35·7	53	35·9	252	34·7
All ages	261	36·0	35	25·7	79	25·3	187	22·7	753	25·6

C.P.—Complicated pneumoconiosis.

TABLE 11
TYPE OF PNEUMOCONIOSIS IN RELATION TO DISABLEMENT

Age Group	Total Disablement			Partial Disablement			No Disablement		
	All Types	Complicated Pneumoconiosis		All Types	Complicated Pneumoconiosis		All Types	Complicated Pneumoconiosis	
		No.	%		No.	%		No.	%
30 and under	0	0	0·0	0	0	0·0	0	0	0·0
31–40	4	1	25·0	16	3	18·8	10	0	0·0
41–50	28	14	50·0	234	35	14·9	37	0	0·0
51–60	107	62	57·9	424	84	19·8	22	0	0·0
61 and over	166	102	61·4	259	57	22·0	8	0	0·0
All ages	305	179	58·7	933	179	19·2	77	0	0·0

infection, notably tuberculosis, but relative to the present cases we have no direct information on this aspect of the problem. It is possible, however, to study our cases in conjunction with official statistics on tuberculosis. According to the latest published figures of the Registrar General for Scotland (1936) the comparative mortality rate of coal-mining occupations from all causes is 108·2 (base 100). It is stated that this mortality rate is consistently above the average for each age and is largely due to deaths from accidental causes and respiratory diseases. Mining and quarrying occupations are listed among those showing a low mortality rate from tuberculosis (70), but on the other hand these same occupations have a high mortality rate from bronchitis and pneumonia (151).

The proportion of complicated pneumoconiosis in all cases is almost identical in each of the four coalfields, but the mean annual certification rate varies throughout these coalfields (see Table 4). The relation of the certification rates of pneumoconiosis to the death rates for respiratory tuberculosis and for bronchitis and pneumonia in the corresponding areas is shown in Table 12.

In this comparison there is a possible fallacy in that the population used by the Registrar General comprises all ages, whereas the pneumoconiosis certification rate is based on a male population aged 14 years and upwards. Furthermore, the figures relate to mortality from tuberculosis and not to incidence.

TABLE 12
PNEUMOCONIOSIS IN RELATION TO RESPIRATORY TUBERCULOSIS AND BRONCHITIS AND PNEUMONIA

Area	Deaths per 1000 Population		Corresponding Coalfield and Pneumoconiosis Certification Rate		
	Respiratory Tuberculosis	Bronchitis and Pneumonia			
Lanark County ..	0·82	2·97			
Airdrie Burgh ..	0·61	2·26			
Hamilton Burgh ..	0·66	2·43		Simple	3·36
Motherwell and Wishaw Burghs	0·61	2·49	A	Complicated	1·25
Stirling County ..	0·57	1·85		All	4·61
Falkirk Burgh ..	0·70	2·38			
Fife County ..	0·52	1·47			
Cowdenbeath ..	0·42	—		Simple	1·47
Lochgelly ..	0·40	—	B	Complicated	0·49
Leven	0·38	—			
Buckhaven and Methil ..	0·57	—		All	1·96
Midlothian County	0·78	1·96			
Dalkeith	0·51	—			
Loanhead ..	0·64	—		Simple	2·66
East Lothian County	0·54	1·18	C	Complicated	1·07
Tranent	1·01	—			
Prestonpans ..	0·49	—		All	3·73
Ayr County ..	0·57	1·69		Simple	1·66
Cumnock and Holmhead ..	0·44	—	D	Complicated	0·68
					2·34

The certification rate of pneumoconiosis of both the simple and complicated types in the four main Scottish coalfields runs fairly parallel to the death rates for respiratory tuberculosis and respiratory infections in the same area. Before 1936 Ogle (1885) and Tatham (1897) commented on the low tuberculosis mortality among coal miners. Many other observers have confirmed their statements and scientists have sought an explanation. Gardner (1933) demonstrated that "coal dust inhibits the growth of the tubercle bacillus" and Cummins (1934) writes.

> "The coal miner seems to escape because coal dust so modifies and detoxicates the phthisive lung lesions that the condition of tuberculosis, though present, escapes recognition and is therefore absent from the death reports on which the Registrar General's death statistics are based."

In effect the submission of these authors and many others is that infective fibrosis, massive fibrosis, or complicated pneumoconiosis represents modified tuberculosis.

Our analysis of 1,315 cases of pneumoconiosis in Scottish coal mines shows that the incidence of certification in the separate coalfields appears to be related to the tuberculosis mortality rate in the same areas. This applies equally whether the disease is simple or complicated pneumoconiosis. This then would appear to suggest that *if* there is some relation between coal miners' pneumoconiosis and tuberculous infection it is in inducing the disease in general rather than any particular type.

What then determines complicated pneumoconiosis? In our opinion, the period at risk is a material factor and this is reflected in the age of the patient. Stone dust may be another factor. These factors inculpate both the quantity and quality of dust. It is not claimed that we have proved that complicated pneumoconiosis is essentially due to the quantity and quality of the noxious dust cloud, but we do suggest that these are important factors hitherto diminished by the emphasis on the part played by the tubercle bacillus.

In the elucidation of the aetiology of pneumoconiosis this complex problem of the separate or combined roles of dust and the tubercle bacillus is the greatest challenge to the experimental pathologists. Though as yet we do not know the answer, the control of airborne dust demands the unremitting attention of all engaged in mining coal (Bryan, 1949, 1950a and b; Meiklejohn, 1950).

Summary

The occurrence of pneumoconiosis in the Scottish coalfields is examined by a study of all the cases (1,315) certified in this area under the Coal Mining Industry (Pneumoconiosis) Compensation Scheme, 1943, and the National Insurance (Industrial Injuries) Act, 1946, during the six years 1944 to 1949.

The geographical and geological features of the area are briefly described.

Pneumoconiosis has been recognized in each of the four main Scottish coalfields and in all colliery districts within these. Since 1944 the number of certifications on account of the disease has substantially increased in the Scottish area and in each of its coalfields.

There is evidence that there has been an increase of cases of the "silicotic" type indicating a real increase in the actual occurrence of the disease within recent times. The broader scope of recent legislation, the retirement of older and unfit miners, the closure of pits, and increased radiological facilities are thought to have contributed to the progressive incidence of certifications in the years under review.

The increase is not uniform in the separate coalfields and local features which may have influenced these differences are discussed. The main factors which would appear to determine a high certification rate in an area are local underground conditions such as dry workings, thin seams, and frequent faulting with the intrusion of stone into the production area.

From an analysis of cases which could reasonably be attached to individual pits, it is submitted that there is no reliable evidence which would justify the common allegation that certain pits are "bad."

The 1,315 certifications have been examined in relation to age and the degree of disability arising from the disease. Certified cases have seldom occurred under 41 years of age, which is roughly the equivalent of 21 years of colliery work. In this matter age reflects fairly accurately the length of exposure in years to the dust risk.

It is concluded that the degree of disablement advances with age. It is further shown that complicated pneumoconiosis, a more advanced type of the disease than simple pneumoconiosis, is more common in the older age groups and that this form of the disease is invariably associated with some degree of disability and is at the same time the most common cause of total incapacity for work.

The certifications have been reviewed in relation to special occupational groups and the age of workmen in these groups.

The possible relationship of pneumoconiosis to tuberculous infection is discussed, and it is revealed that the certification rates of pneumoconiosis in the Scottish coalfields appear to be related to the mortality rates from tuberculosis of the lungs in the same geographical areas.

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APPENDIX

A: Central Coalfield (Lanarkshire Basin, Douglas Valley, and N.E. Stirlingshire)

A1. Northern Lanarkshire: Cadder, Chryston, Kilsyth, Twechar, Falkirk, Denny, Larbert, Stirling, and Bo'ness districts.

A2. Central Lanarkshire: Airdrie, Coatbridge, Bellshill, Cambuslang, Uddingston, Hamilton, Motherwell, Wishaw, and Larkhall districts, and the Douglas district.

A3. Shotts and Wilsontown.

A4. West Lothian and West Midlothian: Bathgate, Armadale, and Whitburn districts.

B: Fife and Clackmannan Coalfield

B1. Clackmannan and West Fife: Clackmannan, Comrie, and Valleyfield districts.

B2. Central Fife: Dunfermline, Cowdenbeath, and Lochgelly districts.

B3. East Fife: Kirkcaldy, Wemyss, and Leven districts.

C: Lothians Coalfield (Mid and East Lothian)

C1. Midlothian: Musselburgh, Dalkeith, and Roslin-Loanhead districts.

C2. East Lothian: Prestonpans, Tranent, and Ormiston districts.

D: Ayrshire Coalfield including Sanquhar-Kirkconnel Basin in Dumfriesshire

D1. Central Ayrshire: the larger, and economically the more important, comprising Mauchline, Cumnock, New Cumnock, Annbank, and Dalmellington districts.

D2. Other Ayrshire coal workings comprising North Ayrshire (Dreghorn and Kilmarnock districts), South Ayrshire (Dailly district) and Dumfriesshire (Sanquhar and Kirkconnel districts). These lie in different directions on the periphery of the Central Ayrshire area and are included in one area as individually they do not employ a sufficient number of workers to provide units of reasonable size for analysis.

These four main divisions and their sub-divisions have been so defined as they are natural geographical units of reasonable size and conform closely to the arrangement in the Scottish Coalfields Report.

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A PILOT INVESTIGATION INTO THE OCCURRENCE OF PNEUMOCONIOSIS IN LARGE POWER STATIONS IN SOUTH WALES

BY

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In the large electricity generating stations where coal is used both the coal and the resultant ash are enclosed and handled mechanically. Nevertheless, considerable quantities of dust are found on the tops of machinery, on ledges, and in crevices, and the workmen in some parts of the station get their faces and clothes covered with dust. As there have been, as far as it is known, no previous studies of the possibility of pneumoconiosis arising from exposure to dust in electricity generating stations, it was decided in the first instance to examine radiologically a group of men employed in these stations in South Wales. South Wales was chosen because the mobile *x*-ray unit of the M.R.C. Pneumoconiosis Research Unit, which could ensure films of a high technical standard, was close at hand, and pneumoconiosis was more likely to occur in stations handling coal from the South Wales fields where miners show a higher incidence of dust disease than in any other British coal field. It was also supposed that in this region, where the association of pneumoconiosis with coal dust is so well known, the cooperation from the men would be good. There was, however, one disadvantage which was not overlooked. Many of the men employed in power stations had also worked in coal mines for varying periods. If pneumoconiosis were found in these men it would be difficult to know which occupation had caused it.

Four large stations were selected for the investigation because they were conveniently situated and were representative of the different conditions in this region, for example, in the type of coal used and the methods of stoking boilers. There appeared to be several sources of exposure to dust: from coal tipping in the bunker houses, and from the pulverizing mills and large pipes conveying the pulverized fuel, from the ash from boilers and precipitators, although much of the ash is carried away by water; from the maintenance and repair of mechanical and electrical equipment by fitters and their mates, when a large amount of settled dust is disturbed, particularly in dismantling equipment; and from the maintenance and cleaning of boilers and precipitators.

It was not possible to separate the men employed on these jobs into occupational groups as most of the men are constantly changing their type of work. Bricklayers and laggers who are continually employed on this work, can, however, be considered separately. The bricklayers go inside boilers to chip away worn and broken silica bricks. During this work the boilers are open and a gentle air stream is passed through them but the men are exposed to considerable quantities of siliceous dust. The laggers strip asbestos off steam pipes being repaired, and are exposed to clouds of fine asbestos dust.

Method of Investigation

Approximately 50% of the men at risk volunteered for examination. Some refused to be examined, others who were on shift work were missed, and in two stations an influenza epidemic caused many to be absent. The date of birth and the length of past and present occupations within and outside the power stations were recorded. Large films were taken, and were read on two separate occasions without reference to the industrial histories by Dr. A. L. Cochrane and myself. They were classified by the method described by Cochrane, Davies, and Fletcher (1951).

Results

Five hundred and seventy-two men were examined. Table 1 shows the numbers examined and at risk in each age group according to the time they had worked in power stations.

TABLE 1

ANALYSIS OF THE TOTAL NUMBER OF MEN AT HAZARD ACCORDING TO AGE AND YEARS SPENT IN THE POWER STATIONS

Age Groups (years)	Years Worked in the Power Stations														
	Under 10			10–19			20–29			30 and over			Total		
	Total	No. X-rayed	%	Total	No. X-rayed	%	Total	No. X-rayed	%	Total	No. X-rayed	%	Total	No. X-rayed	%
16–29 ..	200	95	47·5	—	—	—	—	—	—	—	—	—	200	95	47·5
30–39 ..	204	124	60	30	15	50	—	—	—	—	—	—	234	139	59
40–49 ..	210	120	57	87	45	51	5	4	80	6	2	33	308	171	55
50 and over	197	69	35	133	66	50	18	13	72	48	19	40	396	167	42
Total ..	811	408	50	250	126	50	23	17	74	54	21	39	1,138	572	50

Seventy-one per cent. of the men at risk had worked for less than 10 years in power stations and 93% for less than 20 years. Half of the men who were 50 years old or more had worked in these stations for less than 10 years. Thus the length of the working period has not the usual relationship with age because the electricity generating industry has roughly doubled its output every seven years since 1932, and in South Wales many men enter this industry from the mines and the steel industry as the work is less arduous. The sample is, unfortunately, unsatisfactory from the statistical point of view because it is a volunteer sample with all its inherent weaknesses.

Incidence of Pneumoconiosis.—There were 57 men with pneumoconiosis, and every one of them had worked underground.

There were 407 men who had never worked underground, and it will be seen from Table 2 that

TABLE 2

ANALYSIS BY YEARS OF EXPOSURE OF MEN WORKING IN POWER STATIONS WHO HAD NEVER WORKED UNDERGROUND

Years in Power Stations	No. of Men	No. with Pneumoconiosis
Under 10	290	*
10–19	86	Nil
20–29	15	
30 and over	16	
Total	407	

117 had worked in power stations for more than 10 years, yet none showed any radiological evidence of pneumoconiosis. In this group there were seven bricklayers and three mates; one bricklayer had worked for 11 years, the remainder for seven years or less. There were also four laggers and three mates. One lagger had worked for 10 years and the remainder for less than six years. There were 165 who had worked both underground and in power stations and 57 were found to have definite radiological evidence of pneumoconiosis. In Table 3 it is shown that the severity of pneumoconiosis is related to the period worked underground. Of the 13 men with complicated pneumoconiosis only one had worked for less than 20 years in a coal mine.

Other Diseases.—Fourteen men had radiological evidence of pulmonary tuberculosis other than healed primary lesions; of these lesions three were thought to be active, and the men were referred to the chest clinic.

Discussion

Since the conditions in the power stations were apparently dusty, it was rather surprising to find no evidence of pneumoconiosis among the men examined who had not worked underground but it must be remembered that only half the workers were examined. While there is no reason to suppose that there would be pneumoconiosis in those who did not volunteer, this possibility cannot be excluded. However, Cochrane (1951) found in a colliery survey that there was less pneumoconiosis in the last volunteers examined than in the first volunteers, so that it is unlikely.

Similar conditions found in screening and trimming coal and in processing it to make patent fuels are known to produce pneumoconiosis (Gough, 1940; Hart and Aslett, 1942). Ash-dust from coke fires in gas works in association with sulphur dioxide is thought by Dunner, Hardy, and Bagnall (1949) to cause pneumoconiosis, and it has also been found in boiler-scalers cleaning the flue dust in the fire tubes arising from coal and other fuels (Harding and Massie, 1951).

The reasons for finding no evidence of pneumoconiosis in the volunteers examined is probably chiefly the high rate of ventilation in power stations

TABLE 3

ANALYSIS OF MEN WHO HAD WORKED IN BOTH COAL MINES AND POWER STATIONS BY YEARS WORKED UNDERGROUND AND AMOUNT AND SEVERITY OF PNEUMOCONIOSIS

Years Worked Underground	Total No. of Men	No. with Pneumoconiosis				Total Pneumoconiosis Cases	Percentage Pneumoconiosis Cases
		Category 1	Category 2	Category 3	Complicated Pneumoconiosis		
Under 10	68	2	1	—	—	3	4·4
10–19	51	10	7	1	1	19	37·2
20–29	35	5	8	6	6	25	71·4
30 and over ..	11	3	1	—	6	10	90·9
Total	165	20	17	7	13	57	10

provided by forced draught fans supplying air to the boilers. The intake ducts of these fans are at the top of the building and take in air at the rate of 300,000–500,000 cu. ft. per min. This produces an enormous rate of air change at every working level inside the station and should keep the concentration of atmospheric dust at a low level. There is little or no air movement immediately above solid objects such as pipes, machinery, and ledges and it is here that the dust collects, but it is doubtful if the particle size of settled dust is small enough to produce disease (Hatch, 1951). Further, the majority of workmen seen had not spent many years working in power stations and some, such as boiler cleaners and maintenance men, do this work only in the summer months. A general inspection of bricklaying and lagging suggests that there is a risk of pneumoconiosis here but probably neither the number of men examined nor the lengths of exposure were sufficient to show it.

At the worst the risk of pneumoconiosis in power stations cannot be very high, but another *x*-ray survey of the same men at a later date would give more conclusive evidence.

Summary

Five hundred and seventy-two men out of 1,138 from four large power stations were radiologically examined using large films. Fifty-seven men were found to be suffering from pneumoconiosis and every one of them had worked underground in coal mines. No case of pneumoconiosis was found in the 407 men who had not worked underground. And of these 117 had worked for more than 10 years and 31 for more than 20 years in power stations. The reasons for this are discussed. It is thought that a hazard exists, especially to bricklayers and laggers and their mates, and also to boiler cleaners and maintenance men, but the exposure has probably been too short to produce pneumoconiosis. The very high rate of ventilation may be responsible for preventing disease in most of the workers in the power stations.

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THE EXPECTED FREQUENCY OF BLADDER TUMOUR IN WORKS POPULATIONS

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It has long been recognized that certain occupations, such as the manufacture or use of some dyestuff intermediates, have caused an increase in the frequency of either papilloma or carcinoma of the bladder. It is unnecessary here to make detailed references to papers on this topic, since an extensive review was written by Goldblatt in 1947.

There is little or no certainty, however, as to how far such an occupational risk affects other industries or occupations, and before an occupational risk of this sort can be recognized it is necessary to show that more cases are occurring amongst men employed in a particular environment than occur amongst men not so employed. This comparison makes it necessary to have an estimate of the expected frequency of the disorder that would occur among the same men if no environmental risk were affecting them.

Unfortunately, sickness records for England and Wales are not sufficiently complete to enable an estimate to be made of the frequency with which papilloma or carcinoma of the bladder occurs in living patients, but it is possible to form a reasonably precise estimate of the number of death certificates which mention papilloma or carcinoma of the bladder for males in England and Wales. Such an estimate will give the frequency of death certificates mentioning tumour of the bladder at the average rate for males in England and Wales, a figure not quite the same as the death rate for the disorder, since some of the deaths are assigned to other causes, although the certificate also mentions bladder tumour. For the present purpose the estimate of certificates mentioning tumour of the bladder is more appropriate than the death rate.

It is also possible to obtain a copy of the death certificate of a deceased person, so that if death records are kept by a firm the number of death certificates mentioning tumour of the bladder that actually occur can be found, and a comparison of the number expected and the number found can be made. Collecting the information about the actual number of death certificates with mention of tumour of the bladder may present some difficulty. For the future, this could partly be solved by the employing firm keeping death records, but this would not give a complete record, since it would not be practicable to complete such records for all men who had left the particular employment.

By arrangement with the Registrar General an alphabetical register of all deaths in England and Wales of males whose death certificates contained mention of bladder tumour is at present being maintained at the Chester Beatty Research Institute. This covers the years 1936–50, but will be extended from year to year as information becomes available. With adequate safeguards against misuse of the information contained in the register, it would be possible to arrange for lists of men on the nominal roll to be checked against this register with a view to full death certificates being obtained from the General Register Office where necessary. To save labour such lists should be the nominal roll used to form the estimate with the names of men known to be alive removed from it. This procedure would also ensure that any desired degree of industrial reticence could be preserved. Should a demand become apparent, the register could also be extended to cover the period 1921–35.

It thus becomes possible for medical officers or other responsible persons having access to works records to investigate whether or not there is any reason to believe that a particular industry, occupation, or process gives rise to tumours of the urinary bladder. It is of course necessary that the works records should be sufficiently complete to enable this to be done.

The purpose of this paper is to describe how the

TABLE A FACTORS

Period of Observation (X)	Age at Entry (Z)																	
	15·0	17·5	20·0	22·5	25·0	27·5	30·0	32·5	35·0	37·5	40·0	42·5	45·0	47·5	50·0	52·5	55·0	57·5
2·5	0·00	0·00	0·00	0·01	0·02	0·04	0·08	0·15	0·29	0·52	0·92	1·56	2·54	4·01	6·06	8·94	12·67	17·38
5·0	0·00	0·00	0·01	0·02	0·04	0·09	0·17	0·32	0·58	1·02	1·72	2·87	4·42	6·69	9·78	13·81	18·84	24·86
7·5	0·01	0·01	0·02	0·05	0·09	0·19	0·35	0·63	1·11	1·88	3·01	4·81	7·27	10·59	14·89	20·23	26·57	33·78
10·0	0·01	0·02	0·05	0·10	0·20	0·37	0·68	1·20	2·03	3·30	5·17	7·81	11·35	15·91	21·53	28·19	35·64	43·72
12·5	0·02	0·05	0·11	0·20	0·39	0·72	1·27	2·16	3·51	5·51	8·30	12·05	16·85	22·74	29·63	37·35	45·58	54·08
15·0	0·05	0·11	0·21	0·41	0·75	1·33	2·26	3·69	5·80	8·74	12·67	17·70	23·82	30·95	38·89	47·32	55·88	64·16
17·5	0·11	0·21	0·42	0·77	1·38	2·35	3·85	6·04	9·11	13·21	18·43	24·77	32·13	40·26	48·84	57·45	65·76	73·35
20·0	0·22	0·42	0·78	1·40	2·41	3·95	6·23	9·41	13·65	19·05	25·58	33·14	41·45	50·15	58·85	67·14	74·65	81·16
22·5	0·42	0·79	1·42	2·44	4·02	6·35	9·62	13·99	19·54	26·25	33·97	42·44	51·25	60·04	69·32	75·78	82·17	87·38
25·0	0·78	1·41	2·44	4·05	6·42	9·76	14·23	19·90	26·75	34·63	43·24	52·19	61·02	69·31	76·72	83·02	88·10	92·00
27·5	1·38	2·41	4·03	6·43	9·81	14·34	20·13	27·10	35·11	43·85	52·90	61·80	70·12	77·50	83·72	88·69	92·47	95·21
30·0	2·36	4·09	6·37	9·76	14·35	20·21	27·29	35·41	44·27	53·42	62·39	70·74	78·10	84·27	89·17	92·86	95·50	97·29
32·5	3·89	6·26	9·65	14·27	20·15	27·30	35·53	44·49	53·73	61·79	71·18	78·56	84·70	89·55	93·17	95·75	97·47	98·56
35·0	5·68	9·45	14·04	19·95	27·15	35·45	44·50	53·85	62·99	71·45	78·86	85·01	89·83	93·40	95·95	97·59	98·65	99·28
37·5	9·17	13·72	19·62	26·84	35·19	44·32	53·77	63·01	71·55	79·02	85·19	90·01	93·57	96·06	97·69	98·72	99·32	99·66
40·0	13·30	19·15	26·36	34·74	43·95	53·50	62·84	71·49	79·04	85·25	90·11	93·66	96·15	97·79	98·77	99·36	99·68	99·88
42·5	18·55	25·73	34·11	43·38	53·01	62·49	71·25	78·91	85·22	90·13	93·71	95·33	97·81	98·78	99·38	99·70	99·89	99·94
45·0	25·04	33·31	42·61	52·34	61·94	70·84	78·63	85·05	90·04	93·68	96·19	97·82	98·82	99·39	99·71	99·86	99·94	99·98
47·5	32·33	41·65	51·46	61·19	70·25	78·20	84·76	89·87	93·60	96·15	97·81	98·82	99·40	99·71	99·87	99·94	99·98	99·99
50·0	40·50	50·39	60·24	69·48	77·62	84·37	89·61	93·45	96·08	97·78	98·81	99·40	99·72	99·87	99·94	99·98	99·99	100·00
52·5	49·11	59·10	68·53	76·89	83·83	89·25	93·22	95·96	97·71	99·36	99·38	99·72	99·88	99·94	99·98	99·99	100·00	100·00
55·0	57·76	67·39	75·98	83·16	88·79	92·93	95·78	97·62	98·73	99·72	99·70	99·88	99·95	99·98	99·99	100·00	100·00	100·00
57·5	66·04	74·89	82·35	88·22	92·56	95·56	97·49	98·67	99·33	99·85	99·86	99·95	99·99	99·99	100·00	100·00	100·00	100·00
60·0	73·61	81·36	87·52	92·10	95·27	97·33	98·58	99·29	99·66	99·93	99·93	99·99	99·99	100·00	100·00	100·00	100·00	100·00
62·5	80·22	86·69	91·54	94·92	97·13	98·47	99·23	99·65	99·84	99·97	99·97	99·99	100·00	100·00	100·00	100·00	100·00	100·00
65·0	85·78	90·86	94·49	96·87	98·33	99·16	99·60	98·82	99·93	99·99	99·99	100·00	100·00	100·00	100·00	100·00	100·00	100·00
67·5	90·07	93·98	96·50	98·16	99·08	99·57	99·81	99·92	99·97	99·99	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
70·0	93·25	96·19	97·95	98·97	99·51	99·78	99·91	99·96	99·99	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

TABLE B FACTORS

Date of Mid-point of Period of Observation (w)	Age at Entry (Z)																	
	15·0	17·5	20·0	22·5	25·0	27·5	30·0	32·5	35·0	37·5	40·0	42·5	45·0	47·5	50·0	52·5	55·0	57·5
1920	0·3787	0·3832	0·3877	0·3922	0·3967	0·4012	0·4057	0·4102	0·4147	0·4192	0·4237	0·4282	0·4327	0·4372	0·4417	0·4462	0·4507	0·4552
1922	0·4025	0·4070	0·4115	0·4160	0·4205	0·4250	0·4295	0·4340	0·4385	0·4430	0·4475	0·4520	0·4565	0·4610	0·4655	0·4700	0·4745	0·4790
1924	0·4263	0·4308	0·4353	0·4398	0·4443	0·4488	0·4533	0·4578	0·4623	0·4668	0·4713	0·4758	0·4803	0·4848	0·4893	0·4938	0·4983	0·5020
1926	0·4501	0·4546	0·4591	0·4636	0·4681	0·4726	0·4771	0·4816	0·4861	0·4906	0·4951	0·4996	0·5041	0·5086	0·5131	0·5176	0·5221	0·5266
1928	0·4739	0·4784	0·4829	0·4874	0·4919	0·4964	0·5009	0·5054	0·5099	0·5144	0·5189	0·5234	0·5297	0·5324	0·5369	0·5414	0·5459	0·5504
1930	0·4977	0·5022	0·5067	0·5112	0·5157	0·5202	0·5247	0·5292	0·5337	0·5382	0·5427	0·5472	0·5517	0·5562	0·5607	0·5652	0·5697	0·5742
1932	0·5215	0·5260	0·5305	0·5350	0·5395	0·5440	0·5485	0·5530	0·5575	0·5620	0·5665	0·5710	0·5755	0·5800	0·5845	0·5890	0·5935	0·5980
1934	0·5453	0·5498	0·5543	0·5588	0·5633	0·5678	0·5723	0·5768	0·5813	0·5858	0·5903	0·5948	0·5993	0·6038	0·6083	0·6128	0·6173	0·6218
1936	0·5691	0·5736	0·5781	0·5826	0·5871	0·5916	0·5961	0·6006	0·6051	0·6096	0·6141	0·6186	0·6231	0·6276	0·6321	0·6366	0·6411	0·6456
1938	0·5929	0·5974	0·6019	0·6064	0·6109	0·6154	0·6199	0·6244	0·6289	0·6334	0·6379	0·6424	0·6469	0·6514	0·6559	0·6604	0·6649	0·6694
1940	0·6167	0·6212	0·6257	0·6302	0·6347	0·6392	0·6437	0·6482	0·6527	0·6572	0·6617	0·6662	0·6707	0·6752	0·6797	0·6842	0·6887	0·6932
1942	0·6405	0·6450	0·6495	0·6540	0·6585	0·6630	0·6675	0·6720	0·6765	0·6810	0·6855	0·6900	0·6945	0·6990	0·7035	0·7080	0·7125	0·7170
1944	0·6643	0·6688	0·6733	0·6778	0·6823	0·6868	0·6913	0·6958	0·7003	0·7048	0·7093	0·7138	0·7183	0·7228	0·7273	0·7318	0·7363	0·7408
1946	0·6881	0·6926	0·6971	0·7016	0·7061	0·7106	0·7151	0·7196	0·7241	0·7286	0·7331	0·7376	0·7421	0·7466	0·7511	0·7556	0·7601	0·7646
1948	0·7119	0·7164	0·7209	0·7254	0·7299	0·7344	0·7389	0·7434	0·7479	0·7524	0·7569	0·7614	0·7659	0·7704	0·7749	0·7794	0·7839	0·7884
1950	0·7357	0·7402	0·7447	0·7492	0·7537	0·7582	0·7627	0·7672	0·7717	0·7762	0·7807	0·7852	0·7897	0·7942	0·7987	0·8032	0·8077	0·8122
1952	0·7595	0·7640	0·7685	0·7730	0·7775	0·7820	0·7865	0·7910	0·7955	0·8000	0·8045	0·8090	0·8135	0·8180	0·8225	0·8270	0·8315	0·8360
1954	0·7833	0·7878	0·7923	0·7968	0·8013	0·8058	0·8103	0·8148	0·8193	0·8238	0·8238	0·8328	0·8373	0·8418	0·8463	0·8508	0·8553	0·8598

Linear interpolation is permissible for both w and Z. The constants are 0·0119 per year for w and 0·00178 per year for Z.

estimate of the number of bladder tumours at the mean rate for males in England and Wales (referred to as the expected number) can be made. The theoretical basis of the calculation is complex, but an understanding of the full details of this basis is unnecessary for forming the estimate, and they have therefore been described elsewhere (Case, 1953).

The underlying principles of the method, which is a form of cohort analysis, are that the disease becomes progressively more common with increasing age of the individual until 80 is attained, and that the death rate from this cause at any given age has increased in a more or less regular manner between 1920 and the present day. In addition, death rates from all causes have tended to decrease at any given age during the same time.

An extensive study (Case, 1953) of the death rates from bladder tumour for the 30 years 1921–50 has made it possible to construct tables of factors (Tables A and B) which will allow these changes to be assessed with reasonable accuracy when considering a group (cohort) of men originally in a stated age group (Z) who enter a specified environment between certain dates and who are then observed for X years to the date of assessment. The men are considered as having acquired bladder tumours at the rate that would have obtained if the whole of the X years had the risks at each age current for the date w, which is the mid-point between the date of starting and the date of assessment.

The Table A factors represent the percentage reached by the date of assessment of the final incidence of death from bladder tumour that would occur in a cohort of men originally aged Z who were observed until death from any cause had wiped out the cohort. The Table B factors show what this final incidence would be (as a percentage of the number of men in the original cohort) for men starting at different ages and different dates.

Table C gives the highest estimated value that makes it possible to assume an environmental risk.

TABLE C

HIGHEST ESTIMATED VALUE PERMITTING THE ASSUMPTION THAT THE NUMBER OF DEATH CERTIFICATES INDICATES AN ENVIRONMENTAL RISK

No. of Bladder Tumour Death Certificates Actually Found (1)	Highest Estimated Value Making Nos. in Col. 1 Suspect (2)	Highest Estimated Value Making Nos. in Col. 1 Excessive (3)
1	0·052	0·020
2	0·356	0·215
3	0·818	0·567
4	1·367	1·016
5	1·970	1·530
6	2·613	2·089
7	3·285	2·684
8	3·981	3·307
9	4·695	3·953
10	5·426	4·619
11	6·169	5·300
12	6·920	5·996
13	7·690	6·705
14	8·854	7·424
15	9·247	8·153

Methods

Works Records.—It is necessary to search the works records and find what men have worked in the environment under consideration, the date at which they entered that environment, and their age when they did so. It is desirable to define a lower limit for time of employment by the firm (say six months) since people who are only employed for a week or so tend to be migrants and it would be difficult to trace their death certificates when they died. Subsequent withdrawal from the environment by change of occupation or retirement does not affect the method except insofar as it makes the proof of identity of the man and a possible death certificate more tedious. Having compiled such a list of men, which will be described as a nominal roll, it should be set out in the following manner.

The men should be grouped according to the date at which they started work in the environment under consideration ; this will be called the date of entry. The dates of entry should be arranged in convenient groups, preferably of five years each, and the date of entry used for the calculation is the date of the mid-point of that group.

The men in each date of entry group should be divided further according to how old they were at that date. This age is termed the age at entry, and these ages should be arranged in groups of 10, or, preferably, five years, and the ages at entry used for the calculation are the ages at the mid-points of these groups. An example of this process is shown in Table 1. The age groups should be chosen so that the mid-points lie on a figure ending in 2·5, 5·0, 7·5, or 0·0

It is now necessary to decide at what date the final assessment is to be made. For example, a process has records extending from 1920 to 1950, and death records have been searched up to January 1, 1950. The final assessment is therefore made at 1950, and this is called the end of the period of observation. This should be chosen in relation to the age of entry groups so that the X values lie on figures ending in 2·5, 5·0, 7·5, or 0·0.

Now for each age of entry group there is a mid-point, which is called Z, and for each date of entry group there

TABLE 1

A HYPOTHETICAL NOMINAL ROLL TO SHOW METHOD OF EVALUATING X, w, AND Z

Date of Entry	Jan. 1, 1920–Dec. 31, 1924					Jan. 1, 1925–Dec. 31, 1929					Jan. 1, 1930–Dec. 31, 1934					Jan. 1, 1935–Dec. 31, 1939					Jan. 1, 1940–Dec. 31, 1944					Jan. 1, 1945–Dec. 31, 1949					
Mid-point of date of entry group	1922·5					1927·5					1932·5					1937·5					1942·5					1947·5					
X = Date of final assessment minus date at mid-point of date of entry group	27·5					22·5					17·5					12·5					7·5					2·5					
w = Date at mid-point between mid-point of date of entry group and date of assessment	1936·25					1938·75					1941·25					1943·75					1946·25					1948·75					
Number of men in each age at entry group	10	23	27	11	2	15	28	29	12	1	23	37	39	15	3	29	44	50	17	2	94	106	110	50	5	108	127	151	70	9	Total 1,247
Z = Mid-point of age at entry group	17·5	25	35	45	55	17·5	25	35	45	55	17·5	25	35	45	55	17·5	25	35	45	55	17·5	25	35	45	55	17·5	25	35	45	55	
Code number of age at entry group	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
Date of assessment = Jan. 1, 1950	Key to age at entry code number					(1) Between 15 and 19 years					(2) Between 20 and 29 years					(3) Between 30 and 39 years					(4) Between 40 and 49 years					(5) Between 50 and 59 years					

is an interval of time from the date of the mid-point of that group until the end of the period of observation which is called X. There is also at the mid-point of the period of observation a date which is called w.

The values of Z, X, and w are easily found from Table 1 for each group of men. (It must be clearly understood that the Table 1 shown here is an example constructed from a hypothetical population. In practice Table 1 must be constructed for the population being considered, and the values found from this.) Tables A, B, and C are constants and require no further calculation.

All that is now necessary is to multiply the number of men in each small division of Table 1 by the factor from Table A and then by the factor from Table B, the appropriate factors being identified by the value of X, Z, and w for that particular subdivision, add up all these products, and divide by 10,000. This is the estimate of the expected number of death certificates. Table 2 shows the workings of this calculation for the hypothetical population set out in Table 1. The selection of the mid-points of the age of entry groups and the values for X described above ensures that no interpolation is necessary in Table A, where the differences between successive entries are not linear. The w values may necessitate interpolation in Table B, but here the differences are linear and the necessary figures are easily found by inspection.

It is next necessary to compare the number of death certificates actually found from this body of men with this estimate. Obviously, the number actually found can only be a whole number, though the estimate may be a fraction. Table C shows the highest value of the estimate permitted for a number of certificates between 1 and 15 actually found if one is to say that there are more found than would be expected by chance, i.e., if one is to say that there is an environmental risk.

This table gives two figures for the highest estimate of deaths from bladder tumour expected in a particular population. If the calculation gives a figure higher than in column 2 there is no ground for suspicion ; if it gives a figure falling between the numbers in columns 2 and 3 the chance of having obtained so large a difference between expectation and observation from random errors is less than 1 in 20 and it may be suspected that an environmental risk is operating ; if it gives a figure falling below that in the third column this chance is less than 1 in 50 and it may safely be assumed that such a risk is operating.

Summary

A method is described whereby works medical officers or other interested persons with access to

TABLE 2

HYPOTHETICAL POPULATION SHOWN IN TABLE 1 WORKED OUT AS A NUMERICAL EXAMPLE

Date of Entry	Z	X	w	Number of Men (n)	Table A Factor (a)	Table B Factor (b)	Product n × a × b
Jan. 1, 1920–Dec. 31, 1924	17·5	27·5	1936·25	10	2·41	0·5766	13·90
	25·0			23	9·81	0·5901	133·13
	35·0			27	35·11	0·6081	576·42
	45·0			11	70·12	0·6261	482·91
	55·0			2	92·47	0·6441	119·09
Jan. 1, 1925–Dec. 31, 1929	17·5	22·5	1938·75	15	0·79	0·6064	7·16
	25·0			28	4·02	0·6199	69·74
	35·0			29	19·54	0·6379	361·44
	45·0			12	51·25	0·6559	403·38
	55·0			1	82·17	0·6739	55·33
Jan. 1, 1930–Dec. 31, 1934	17·5	17·5	1941·25	23	0·21	0·6360	3·05
	25·0			37	1·38	0·6495	33·12
	35·0			39	9·11	0·6675	237·10
	45·0			15	32·13	0·6855	330·34
	55·0			3	65·76	0·7035	138·73
Jan. 1, 1935–Dec. 31, 1939	17·5	12·5	1943·75	29	0·05	0·6658	0·93
	25·0			44	0·39	0·6793	11·62
	35·0			50	33·51	0·6973	122·38
	45·0			17	16·85	0·7153	204·86
	55·0			2	45·58	0·7333	66·80
Jan. 1, 1940–Dec. 31, 1944	17·5	7·5	1946·25	94	0·01	0·6956	0·63
	25·0			106	0·09	0·7091	6·74
	35·0			110	1·11	0·7271	88·78
	45·0			50	7·27	0·7451	270·84
	55·0			5	26·57	0·7631	101·34
Jan. 1, 1945–Dec. 31, 1949	17·5	2·5	1948·75	108	0·00	0·7254	0·00
	25·0			127	0·02	0·7389	1·85
	35·0			151	0·29	0·7614	33·27
	45·0			70	2·54	0·7794	138·58
	55·0			9	12·67	0·7929	90·39
					Total : 4,103·85		

$$\text{Estimate} = \frac{\text{Total}}{10{,}000} = 0{\cdot}410$$

works records can obtain an idea of whether an environmental risk of bladder tumour formation exists in industries, occupations, or processes in which they are interested, assuming that the works records show the name of the employee, his age or date of birth, and the date at which he started work in the environment to be considered. It is also necessary to find the number of deaths from bladder tumour which have in fact occurred.

The method is applicable to males in England and Wales, and is valid for employment between 1921 and 1950, but probably no great error will be introduced by extending these limits by about a decade either way.

No expert statistical knowledge is required for using the method.

The alphabetical index has been constructed by Miss Margery E. Hosker and Miss Joan T. Pearson.

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METHYLOCTYLBENZENESULPHONATE: A NEW INDUSTRIAL SENSITIZING AGENT

BY

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Occasional outbreaks of dermatitis caused by allergic reactions to chemicals occur in industry (Squire, Cruickshank, and Topley, 1950). For example, the sensitizing properties of the explosive "tetryl" are now well recognized, while on a smaller scale the manufacture of pyrethrum powder gives rise to a large proportion of sensitization rashes among exposed workers (Martin and Hester, 1941). Schwartz, Tulipan, and Peck (1947) provide a long list of substances with sensitizing properties. This paper describes an outbreak of skin disease which was found to be due to a chemical sensitizing agent not previously recognized.

Early in 1951 a new process was begun for the preparation of a highly charged compound, methyltriethylammoniumoctylbenzenesulphonate, for incorporation in an antistatic lubricant. This material was produced originally in a pilot plant and it happened that several chemical engineers exposed to it developed acute transient skin rashes and swelling of the eyelids and lachrymation. The final material is produced in five stages, and the workers concerned held the opinion that the skin troubles were due to some agent in stage 4 of the process.

In stage 4 the following reaction is carried out :

$$\underset{\text{octylbenzene}}{C_6H_5.C_8H_{17}} + \underset{\text{methylchlorosulphonate}}{CH_3OSO_2Cl} \rightarrow \underset{\text{ester}}{CH_3OSO_2.C_6H_4.C_8H_{17}} + HCl$$

This reaction is carried out in the presence of carbon tetrachloride and is aided by heat. The crude ester so formed is a dark brown, tarry liquid which is subsequently washed by a counter-current of water in a wash column. The crude material is very acid and so is liable to cause primary irritation or burns.

Of the other chemicals concerned in this process, octylbenzene is a relatively inert material, carbon tetrachloride is a skin irritant with well known toxic properties, while methylchlorosulphonate is a highly reactive material extremely irritating to the skin. The vapour of this substance causes acute lachrymation and congestion of the nasal mucosa.

However, as the symptoms of the workers and the history of the outbreak were strongly suggestive that the trouble was due, not to primary skin irritation, but to the development of hypersensitivity, investigations were made to determine whether any of the substances involved were sensitizing agents.

Clinical Findings

In all 10 persons had been engaged at one time or another upon the process and all of these had suffered from skin rashes of varying severity. Usually in association with the rash the workers complained of "pricking" of the eyes, swelling of the lids, and lachrymation. Occasionally these symptoms occurred without any accompanying skin trouble. The dermatitis was usually vesicular but sometimes only erythematous. It was associated with intense irritation and local swelling of the subcutaneous tissue. The workers involved stated that the rashes usually followed skin contamination with the crude ester but not infrequently no such incident could be recalled. The majority of rashes occurred for the first time between the second and third month of duty, but in one instance started after five weeks.

The case histories of three workers are described below ; these illustrate the principal clinical features.

Case Reports

Case 1 (E.O.).—This chemical engineer started work on this process in May, 1951. In July, he spilled a solution of the ester upon his arm. He washed at once but during the next 24 hours he developed an irritating vesicular rash on the contaminated area, and the eyelids became swollen. The dermatitis healed in a fortnight. Following this incident his job was changed owing to reorganization in the department, and he no longer came into close contact with any of the materials.

In August, 1951, the patient was on holiday when he suffered from an outbreak of the rash on the area originally affected and he also developed eye symptoms similar to those previously experienced. He then realized that he had put on the shirt which had previously been contaminated with the ester. This shirt had been laundered but had not been worn since the original episode.

Case 2 (L.O.).—This patient first worked on the process in August, 1951. After five weeks he developed an eczematous rash on both forearms ; he had never at any time to his knowledge spilled any of the materials upon the skin. Not until July, 1952, did he experience any eye symptoms, but at this time the eyelids became swollen with lachrymation. He has remained on the process and has had no serious outbreak of skin trouble since his first attack. He states that he gets an occasional erythema of the arms in the evening but this is gone by the next morning. He is also under the impression that his skin has become much drier since working on this job.

FIG. 1.—Vesicular rash on forearm caused by contact with methyloctylbenzenesulphate.

Case 3 (J.W.T.).—This worker started work on this process in July, 1952, and had no trouble in the ensuing seven weeks. In August, however, he spilled some of the crude ester upon the arms. He did not attach much importance to this, but during the next 24 hours a severe dermatitis occurred on both the forearms (Fig. 1). This was vesicular and was associated with gross oedema and erythema of the whole of the forearm. The arms were extremely itchy and in the course of the following 24 hours the eyelids swelled and the eyes became irritable. The swelling was so great as to obscure his vision completely. The dermatitis remained in an active condition for some four days, and in addition to the sites originally affected, patches of erythema occurred in the antecubital fossae and on the sides of the neck.

Four days after the outbreak of the rash he had an eosinophilia of 768 per c.mm. The eosinophils were recorded as 416 per c.mm. 14 days later ; after a month the count had dropped to 204 per c.mm.

The local condition was treated with calamine lotion and he also was given "phenergan," one tablet three times a day. The treatment eased the irritation considerably, and gave him relief from the swelling of the eyelids. During the next week the skin condition subsided gradually.

Patch Tests

Patch tests were performed upon nine of the 10 people who had worked upon the process and had suffered from skin trouble. Tests were made with methylchlorosulphonate and with the ester (methyloctylbenzenesulphonate) as these substances were considered to be the most likely cause of the dermatitis.

In the early stages only crude preparations of the ester were available, and since both these and the methylchlorosulphonate were liable to cause primary irritation upon normal skins, a modified patch test technique was used.

Method.—Small squares of lint (1 cm. square) were soaked in the appropriate dilution of the substances tested. Excess liquid was squeezed out, and the gauze was then placed over the skin of the volar aspect of the forearm. The patch was held in position by a single strip of adhesive plaster and consequently dried rapidly following the evaporation of the solvent. Acetone was used as the vehicle for both substances in the initial tests. In the later tests the methylchlorosulphonate was dissolved in trichlorethylene. This precaution was taken to ensure that no destruction of the methylchlorosulphonate occurred by reaction with acetone. The results were read after 24 hours' contact.

Results.—Of the nine persons tested, eight gave well defined reactions to the ester in concentrations of 1%. No reaction was given to methylchlorosulphonate in the same concentration. Normal subjects did not react to this concentration of the ester, and in a few tests it was found that even the pure substance did not cause any reactions on the normal skin. The reactions produced by crude and pure samples of the ester did not vary appreciably in degree when both were diluted to one in a hundred.

The intensity of the reaction to the ester varied (as might be expected) in different subjects. The mildest reactions were manifested by a square of erythema at the site of the patch. The sites of the hair follicles were marked out by surrounding circles of deeper erythema suggesting some concentration of the material at these points (Fig. 2).

FIG. 2.—Patch test reactions (mild reaction) to 1% methyloctylbenzenesulphonate.

In the more violent reactions an intense uniform erythema was present and there was a "flare" on the surrounding skin. A variable amount of oedema and swelling of tissue in the immediate vicinity occurred.

Two of the subjects complained of mild eye symptoms 48 hours after the test.

No immediate reactions to methyloctylbenzenesulphonate could be elicited by the prick test technique.

Animal Experiments

A sample of the ester was applied to the clipped skin of six guinea-pigs. This caused no immediate reaction but after 72 hours a very faint erythema developed. Seven days later a second application of a 5% solution in acetone of the substance was given. This caused a violent erythema to develop after 24 hours, and the lesion developed over the following five days into a thickened, scaly lesion which subsequently faded.

Skin tests were carried out 14 days after the initial application. The test substances were applied to an area of depilated skin about 1 cm. in diameter by means of a glass rod. The following chemicals were applied :—

(1) Ester (methyloctylbenzenesulphonate): (*a*) 1% in acetone, (*b*) 0·1% in acetone. (2) Methylchlorosulphonate: (*a*) 1% in carbon tetrachloride, (*b*) 0·1% in carbon tetrachloride. (3) Quaternary salt (methyltriethylammoniumoctylbenzenesulphonate): (*a*) 1% in acetone, (*b*) 0·1% in acetone.

Positive reactions were obtained to tests 1 (*a*) and 1 (*b*) only. The reaction was manifested by an area of erythema which was of maximal intensity at 24 hours. In the more highly sensitive animals there was well defined oedema and thickening of the skin at the site of the application of the 1% solution. The reactions to 0·1% ester were similar but of less degree. Control animals gave no reaction to any of the test substances in the concentrations used.

Discussion

The evidence provided shows conclusively that the cause of the outbreak of skin trouble was the methyl ester of octylbenzenesulphonic acid. It is also clear that the ill-effects were due to the fact that this substance is a sensitizing agent. The fact that every person who had come into contact with the material experienced skin trouble and that eight of the nine subjects tested gave positive reactions to a patch test indicates that the material is of a high degree of potency. The reason for the failure of one of the subjects to react to the patch test is not clear. His initial symptoms were very mild and it is possible that he had become desensitized. An alternative explanation is that his initial symptoms were attributable to primary irritation and not to sensitization.

The nature of the clinical response to contact is similar to that reported among workers sensitized to tetryl (Schwartz and others, 1941). In these workers pricking of the eyes and swelling of the lids is noted as a common effect of exposure. This group of eye symptoms is not a common accompaniment of a skin reaction to locally applied drugs although it frequently accompanies a disseminated reaction to these agents.

Examination of the circulating eosinophils was possible in one patient only (Case 3). The high count was further slight evidence of the allergic nature of the reaction. It will be noted that "phenergan" apparently caused some improvement of this patient's subjective symptoms and relieved the swelling of the eyelids. There was no evidence that it modified the course of the skin condition.

The fact that guinea-pigs could be sensitized to this substance not only confirms the clinical findings, but provides a simple method of investigating the possibilities of cross-reactions. This technique has been used with advantage for the investigation of tetryl sensitivity by Gell (1944). It is clear that neither the salt (methyltriethylammonium octylbenzenesulphonate) nor methylchlorosulphonate elicited the reaction.

Landsteiner (1945) propounded the general theory that simple chemical sensitizing agents became antigenic by virtue of the fact that they combined with proteins. This thesis was further substantiated by Gell (1944) and by Gell, Harington, and Rivers (1946). The ester, methyloctylbenzenesulphonate, would appear from its chemical nature to be capable of forming a compound with protein ; linkage might possibly occur with an amino group of the protein via the SO_3 group, by the migration of the methyl group to the nitrogen of the protein amino group. It would form in effect a salt, the amino nitrogen carrying a positive charge, and the sulphonate group a negative charge. Further investigations concerning the mode of action of the compound are in progress.

It is appropriate to note that the outbreak which has been described occurred during the development phase of this particular process. Since this investigation the final plant, in which all of the processes are enclosed, has been installed. No further skin trouble has so far occurred.

Summary

An outbreak of dermatitis in a pilot plant for the production of an antistatic lubricant is described.

This was found to be due to the sensitizing properties of one of the intermediates, viz., methyloctylbenzenesulphonate.

The sensitizing properties of this compound were confirmed by skin tests on guinea-pigs.

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PSYCHOLOGICAL HANDICAP IN RELATION TO PRODUCTIVITY AND OCCUPATIONAL ADJUSTMENT

BY

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The clinical experience of psychiatrists suggests that neurosis, which is sufficiently severe for a person to seek treatment, and inadequate mental ability are handicaps to industrial efficiency. It is often thought by psychiatrists that persons with these handicaps fit badly into industry and produce less than the average (Tredgold, 1949 ; Curran and Guttmann, 1949), and it is a belief shared by many employers and managers. This study was made in an attempt to measure the effects on industrial efficiency of the less serious manifestations of mental ill health such as one would expect to find in ordinary groups of workers in a factory.

The assessment of mental health and industrial efficiency cannot be made with the usual precision of laboratory investigations. The number of groups within factories engaged on comparable work with uniform supervision is surprisingly limited. Moreover, only a firm prepared to lose some of its valuable production time for the future benefit of industry without promise of any direct help in its immediate problems, can be expected to cooperate. The workers themselves may be suspicious of the motives of the study, with understandably hostile attitudes towards psychologists and psychiatrists.

In a previous study of two independent groups of men and women working on conveyor belts an attempt was made to relate their productivity and effectiveness as a group to their psychological characteristics. The results were inconclusive but the experience of this work emphasized the difficulties of making such an investigation in which precise techniques cannot be used (Markowe and Barber, 1952). Nevertheless it was considered that a study should be made of a group in which both productivity and effectiveness could be assessed and related to psychological handicap for *each* worker. The same experimental difficulties would arise but they should be easier to overcome than in a similar study of groups.

The Firm and the Group

The factory, established for more than 50 years in a highly industrialized area, employed some 1,500 men and women and manufactured and marketed accumulators. The favourable economic position of the firm had made it relatively easy to select a stable labour force over many years. All constituent processes, which need not be described here, were carried out in the one factory. The fundamental part of an accumulator is the lead grid which when covered with lead paste forms the battery plate. The grids were made by some 80 " casters " who worked in one department. It was these men whom we chose for this study because they were the largest unselected group of workers available who were engaged on a single process under conditions allowing their productivity to be measured. They were suitable for other reasons, for they differed in their efficiency and experience and their work was continuous over long periods. The study was made between June and December, 1949.

The grid-casters use hand-operated, gas-heated moulds into which they ladle molten metal (mainly lead) from a heated reservoir. After momentary cooling of the mould, they extract the grid plate (or casting) with pincers. Another group of workers impregnate these plates with lead paste and they are subsequently embodied in an accumulator.

The shop is run continuously from 6 a.m. on Monday to 6 a.m. on Saturday in three shifts. The workers change shifts at weekly intervals. The

four charge-hands work on a different shift system from the workers, who thus have constantly changing supervision. The men are paid individually according to the number of grids they produce. Wages are based on a system of payment determined by work-study ; there are no restraints upon possible output other than self-imposed ones.

New employees are examined medically to exclude those who might be harmed by the process, particularly by exposure to lead. All are over 21 years of age and women are not employed. The ages of the men ranged from 22 to 64 years with a median of 37. The distribution of experience in the moulding department was not continuous and could be broken into three groups ; less than 5 years, 33 men, 5-17 years, 18 men, more than 18 years, 29 men. All but one of the workers were married. They were seldom absent from work. Only 17 men were absent more than twice in 1949 and a quarter of the group accounted for four-fifths of the total days lost. The group could not be regarded as a random collection of workers since various selective processes had been operating in its formation over many years, but such processes operate in any similar group of piece workers and it can be reasonably regarded as representative of a group of men employed in light industry.

Methods of Study

Psychological handicap, which is an inexact term, was assessed on two criteria :—

Poor Recent Mental Health.—This was defined as a history of definite disabling psychological illness requiring treatment within the last 12 months, or a history of psychological ill-health evident to the patient or to an observer, but not incapacitating or needing treatment.

Low General Mental Ability.—This was defined as that performance in the Dominoes Test which locates the individual amongst the lowest 10% of the group studied, and would (subject to allowance for age) locate him among the lowest 15% of the general adult population.

Data on height, weight, visual acuity, and haemoglobin estimations were taken from the records of the factory medical department. Special tests of overall muscular strength, static effort tolerance, and Schneider cardiovascular efficiency were made by the medical investigator. Each worker's life history was examined from a psychiatric standpoint, with particular reference to the time of the interview and the previous 12 months. Recent mental and physical health were rated on a four-point scale.

Mental health was deemed to range from rating 1 (healthy, mature, and vigorous) to rating 4 (definite disabling sickness requiring treatment) ; rating 2 covered the rest of the " normal " range, while rating 3 included minor states of ill health, which either did not incapacitate the worker or oblige him to seek treatment. There was a similar range for physical health.

Personality was rated for 13 traits on three-point scales. Twelve were rated as paired opposites as follows : expansive, reticent ; ascendant, submissive ; objective, subjective ; flexible, rigid ; persistent, irresolute ; equable, labile ; emotionally broad, narrow ; emotionally strong, weak ; intelligent, unintelligent ; interested in people, interested in things ; conscientious, irresponsible ; mature, immature. Obsessional traits were also recorded, and ranged from absent or minimal to marked and interfering with work or leisure.

A large number of psychological tests were administered. Full details of these are reported elsewhere (Heron, 1952 ; 1953).

In a separate interview each man was asked for details about his home and his working experience, such as his family obligations, occupational history, housing, time and cost of travelling, and his present job, but questions about rent and wages were not asked.

Each man's adjustment to his work was judged by his absences from work and accidents and the opinion of his supervisors. The actual criteria employed were :—(1) Total number of absences from work irrespective of cause or duration during the calendar year 1949 (holidays excepted) ; (2) total number of days absent from work irrespective of cause during the same period ; (3) total number of accidents as reported to the ambulance room during the same period ; (4) the rating, on a five-point scale, of adjustment to the demands of job situation, obtained by combining the ratings made on each man by six supervisors on each of two occasions five weeks apart. These supervisors included the four charge-hands previously mentioned (Heron, 1952b).

An index of the production of common starter grids was calculated for 45 of the 80 men in the group. It was based on a period of six months and only intact shifts were used, in order to exclude production of other types. This index was compared with the firm's indices which had been calculated for the same 45 men during the same period but had included all types of grid which they had been producing. The statistical comparison gave reasonable grounds for taking a modified personal performance index calculated from the firm's

records as a measure of productivity for all 80 men studied. This was accordingly computed for a 67-week period from September, 1948, to December, 1949 (Heron, 1952b).

Findings

As a group these workers were accepted as the most important and best paid in the factory and acknowledged as the élite of the labour force. In consequence they had been sifted and tested by both management, supervisors, and each other, resulting in a concentration of characteristics which were quite striking clinically and hardly to be expected in the general population.

From the standpoint of recent mental health some 4% were deemed to be suffering from definite disabling sickness requiring treatment, and a further 21% were considered to be in minor states of ill health below the normal range. These unsatisfactory states were varied and comprised anxiety neuroses, mild obsessional disorder, cardiac neurosis, and cerebral arteriosclerosis. It must be recalled that these men were members of a normal working group, and not patients attending a clinic, and they showed a very low rate of absence. Most of the men were expansive, flexible, persistent, extraverted, mature personalities, and devoid of marked obsessional traits. Their intelligence covered a wide range but the average was lower than that found in soldiers between the ages of 18 and 21 years examined while on National Service by the same test at the time this study was being made.

To make comparisons possible, productivity and general mental ability scores were divided into nine grades, which were normalized percentile scores : grade 1 was the highest and 9 the lowest. In the supervisors' ratings of job adjustment, rating 1 was good and 5 was poor ; in recent mental health rating 1 was good and 4 was poor. The group will now be considered comparing the highest and lowest grades or ratings for various characteristics.

Industrial Criteria.—When the workers were divided into groups according to their industrial performance, no clear medical and psychological characteristics emerged to account for their differing work records. Their personality and health, however, showed some relationship to output and adjustment in the less satisfactory groups.

Table 1, dealing with the highest and lowest producers, reveals that experience in the department was equally extensive in both, that recent mental health was mainly within normal limits in both, that general mental ability showed no appreciable difference, and that in general the supervisor's ratings of job adjustment were lower for the lowest producers.

TABLE 1

HIGHEST AND LOWEST PRODUCERS

	Code No.	Age	Experience in M Department (years)	Recent Mental Health	General Mental Ability	Obsessional Rating	Supervisor's Rating on Job Adjustment
Highest Productivity	20	32	2	2*	7	2	3
	24	35	10	2	2	2	1
	25	36	13	1	7	2	2
	35	42	21	1	6	1	2
	37	29	3	2	5	1	2
	40	25	2	3	2	2	3
	55	31	3	2	3	3	2
	75	50	27	2	8	3	1
Lowest Productivity	1	29	3	2	3	2	3
	28	30	2	2	7	2	3
	38	27	3	3	5	1	4
	58	41	25	2	9	2	5
	62	34	mths.	2	5	3	5
	65	53	24	2	8	1	3
	66	52	25	2	5	1	3
	67	41	7	1	4	1	3

* For explanation of ratings see above.

The Highest Producers.—Among the highest producers it is interesting to observe three men, Nos. 24, 75, and 20. The first two had the highest rating from the supervisors for job adjustment, No. 20 had an average rating for job adjustment. No. 24 was a man of high intelligence with strong motivating interests of pride and perfection at work, and at home ambitions for his house and for farming. He made frequent heavy bets and was almost a professional punter. Happy and contented, introverted and asocial, he worked at a steady rhythm, without monotony or exhaustion but with some day dreaming. No. 75, a highly obsessional worker who suffered from a duodenal ulcer and early arteriosclerosis, will be discussed later on in the section dealing with men of low intelligence.

No. 20 was brought up by an excitable widowed mother in a family of six ; his father was killed in 1918 when the subject was one year old, and he lost two brothers on active service. After many changes of job he volunteered for the Army, served abroad, and spent two years as a lance-corporal in Italy where he married a local girl. Since returning home he had raised a family of two, and was buying his own house ; he had no circle of relatives or friends. He was shy and effeminate with subnormal general mental ability, very few interests or drives, timid and moderately meticulous. He did not consider the shift system unduly strenuous, and maintained a constant average performance at work, enjoying good health. His high productivity

might be related to the financial demands of a growing family and of buying a house.

The Lowest Producers.—Recent mental health ratings show the majority of the lowest producers to be within normal limits, only one being subnormal (No. 38). He suffered from moderate anxiety with frequent headaches, lassitude, irritability, and excessive fatigue; he was vaguely ambitious, reticent and poorly integrated, and of average intelligence for the group. He showed poor effort tolerance (Schneider Index 8) and was asocial.

The social background often provides a suggestive explanation for the low production in this group. Some had wage-earning children at home. One man had a highly organized and lucrative domestic occupation (a pig and poultry farm) shared with his father and two fellow shift-workers. He stated that he did not work "all out" at grid-casting, but reserved his energies for family and spare-time farming. He was preoccupied with his farm and was ambitious to own and to be occupied wholly with a small business. He was indeed a satisfied and happy man.

In Table 2 we show the mental state of men in the group consisting of those who obtained both a productivity grading of 6 or worse and a supervisory rating of 4 or 5, i.e. the 2% who were least effective industrially. They were introverted, of rather low intelligence, without ambition and with a history of frequent changes of job. But at least two were in fact ambitious and anxious to progress; they were extraverted, vigorous, and hypomanic individuals who were a source of trouble to their supervisors. One of these was a new worker,

TABLE 2
MENTAL STATE OF LEAST INDUSTRIALLY EFFECTIVE MEN

Code No.	Age	Experience in Moulding Department (years)	Recent Mental Health	General Mental Ability	Obsessional Rating
5	30	2	2*	5	1
38	27	3	3	5	1
44	37	2	1	4	1
47	24	mths.	1	4	2
58	41	28	2	9	2
62	34	mths.	2	5	3
70	33	mths.	2	8	2
79	44	17	1	7	2

* For explanation of ratings see p. 127.

recently married and living with his wife's parents. His wife was earning, and he had many friends. The other man was an experienced worker. He was energetic and sociable, but harried by a menopausal wife who was preoccupied by children, sex, and health. Both men had numerous outside interests, were well integrated and moderately obsessional in temperament, and were rated as having very good mental health.

Absence from Work.—In Table 3 we give the ratings and grades for industrial effectiveness and

TABLE 3
ANALYSIS OF LEAST RELIABLE ATTENDERS

Code No.	Age	Experience in M Department (years)	Recent Mental Health	General Mental Ability	Obsessional Rating	Productivity	Supervisor's Rating on Job Adjustment
1	29	3	2*	3	2	8	3
2	24	2	3	4	2	4	4
15	37	8	2	6	1	5	3
20	32	2	2	7	2	2	3
38	27	3	3	5	1	8	4
43	48	25	2	5	1	6	2
46	50	25	3	4	3	5	1
47	24	1	1	4	2	6	5
66	52	25	2	5	1	9	3
80	29	2	3	3	1	3	3

* For explanation of ratings see p. 127.

mental state of a group of men who were absent during the year both on more than three occasions and for a total of nine days or more, i.e., the 12% least reliable in attendance. Four of these men had a poor record of recent mental health. Three were under 30, well below the median age of the grid-casters.

In this group five of the men who are below 30 years of age account for three-fifths of the absence though only for two-fifths of the total number of days lost during 1949. In other words, these younger men seem to like taking time off frequently but do not stay away for long. The picture for the older men is the reverse. Seven of the 10 served in the last war, and while medical and psychological problems of readjustment may partly explain their high absenteeism, domestic and socio-economic reasons must also be taken into account.

The Worst in Mental Health.—Turning to the extremes of recent mental health, in Table 4 we find that of those with the poorest rating in mental health the clinical findings are varied and include three men with marked obsessional features.

Productivity indices were again mainly about the average for all grid-casters; only one (No. 42) was significantly below the mode. This man was timid, effeminate, and introverted and was suffering from a mild anxiety state. Since taking on the commitments of a new house his wife had worked to increase the family income. He was the youngest of this subgroup and his experience was relatively low; his introversion might well explain his fair

TABLE 4

EXPERIENCE, PRODUCTIVITY, AND JOB ADJUSTMENT OF MEN WITH BEST AND WORST RECENT MENTAL HEALTH RATINGS

	Code No.	Age	Experience in M Department (years)	Productivity	Supervisor's Rating on Job Adjustment
Best	03	33	1	5	3
	09	47	27	6	3
	10	52	25	5	3
	11	31	1	7	3
	21	37	2	5	5
	25	36	13	2	2
	26	49	23	7	2
	27	51	25	7	2
	30	28	3	5	3
	32	36	9	3	3
	35	42	21	2	2
	36	36	1	4	4
	39	32	2	3	3
	44	37	2	6	4
	47	24	Mths.	6	5
	48	48	22	4	2
	59	52	17	7	3
	60	45	23	6	1
	61	43	25	3	3
	64	34	mths.	6	3
	67	41	6	8	3
	68	53	24	7	1
	69	38	mths.	4	4
	74	42	21	4	4
Worst	6	40	12	5	3
	13	35	9	4	5
	16	37	13	6	3
	42	33	12	7	2
	45	64	26	5	3
	46	50	25	5	1
	54	41	9	3	2
	73	46	24	5	2

For full explanation of ratings see p. 126.
Highest = rating 1; Lowest = rating 4.

adjustment rating by the supervisors, since he would tend to keep to himself and his work.

The outstanding findings in this group are again the average range of productivity together with average or fair adjustment to the job as rated by supervisors with the exception mentioned above.

The Best in Mental Health.—Of the men with the best gradings in recent mental health, the mean age was high (40 years), experience was with few exceptions high, productivity was slightly below average, while supervisors' ratings tended to be good (probably because of longer service).

The Lowest in Intelligence.—Of the six men with the lowest intelligence (an I.Q. of 82 or less, corresponding to the lowest 15% of adult men in the general population) with one notable exception (No. 75) all were in the lower 50% of producers. This was unexpected in so far as all but one had over 20 years' experience, forming a sharp contrast with the experience of the most intelligent group (Table 5). As mentioned previously No. 75 was a highly obsessional individual and in the top group for production and for job adjustment; he was most energetic and meticulous, extraverted, had many

TABLE 5

AGE, EXPERIENCE, PRODUCTIVITY, AND JOB ADJUSTMENT RATINGS OF MEN WITH HIGHEST AND LOWEST GENERAL MENTAL ABILITY GRADES IN GROUP OF 80 WORKERS

	Code No.	Age (years)	Experience in M Department (years)	Productivity	Supervisor's Rating for Job Adjustment
Highest General Mental Ability	11	31	1	7	3
	13	35	9	4	5
	24	35	10	1	1
	40	25	2	2	3
	42	32	11	7	2
	74	42	16	4	4
	78	31	1	4	4
Lowest General Mental Ability	17	43	21	5	4
	58	41	25	9	5
	60	45	23	6	1
	65	53	23	8	3
	70	33	Mths.	7	4
	75	50	27	1	1

For explanation of ratings see p. 126.

friends, and spent his spare time as a hairdresser. He suffered from a duodenal ulcer as well as hypertension. No. 58 was an expansive, dominant, and moderately obsessional man who had always wished to become a trapeze artist. He was a fresh and healthy-looking pyknic, happy, contented, and sociable with excellent recent mental health, and a wife and son who both worked and so contributed to the family income.

In Table 6 we give the data of men in the group consisting of those who obtained a mental health

TABLE 6

RATINGS OF MEN DOUBLY HANDICAPPED PSYCHOLOGICALLY

Code No.	Age (years)	Experience in M Department (years)	Obsessional Rating	Productivity	Supervisor's Rating for Job Adjustment
6	40	12	3	5	3
12	27	2	1	4	3
14	43	25	1	7	2
17	43	21	1	5	4
33	44	25	2	5	2
45	64	26	1	5	3
63	58	29	1	7	1
73	46	24	2	5	2

For explanation of ratings see p. 126.

rating of 3 or 4 and also a general mental ability grade of 6 or worse. They were the men who were doubly handicapped psychologically. They had an average output, and in every case but one were rated by the supervisors as reasonably well adjusted to their job.

One of these (No. 14) suffered from a chronic anxiety state with marked somatic complaints ; he worried a great deal and was of a labile temperament. Although a garrulous extravert he had no special friends at work yet represented the group on the Works Committee. He had considerable interests in the Church and many friends, but no recreations beyond his home with three children at school. His wife augmented the family income by working. Another (No. 63) suffered from reactive depression particularly on night duty, was arteriosclerotic and also one of the oldest workers in the department. As well as finding the work fatiguing, especially on nights, he was slow and tremulous. His family commitments were now minimal, with two adult and independent sons earning good wages. These facts, together with the low general mental ability of these two men, would explain their subnormal productivity.

Discussion

For the whole group there was no apparent association between productivity and psychological handicap, but at the extreme ends of the scale intelligence showed a relationship with productivity. Thus the most intelligent men produced slightly more than the average for the group, while the least intelligent were among the poorer producers. But the latter were by no means men with poor mental health. Social influences operating outside the factory played a larger part, it appeared, in determining output than mental health. Men whose income was supplemented by children at work or by a domestic occupation, such as keeping poultry, produced less grids than the average.

The conditions under which the men were working may explain the general lack of association between productivity and psychological handicap for the whole group. Although the management did everything to encourage high output, there were forces of public opinion among the workers which tended to settle what should be " average " earnings and therefore productivity. There were fears that high production might " use up " the work and result in short time, especially in this factory where, as many of the grid casters remember, seasonal working was the practice before 1938. Productivity therefore has an artificial ceiling imposed by the workers themselves, and is dependent on external social and domestic demands. The effect of this internal control on productivity cannot be ignored in any attempt to utilize such measures for purposes of research. It should be noted also that earnings were considerably above national averages and varied between £9 and £11 per week with regular and constant employment.

There is no difficulty in understanding why the most favourable ratings on " job-adjustment " were given to more experienced workers. It is less easy to see why the men who were given unsatisfactory ratings did not include most of those with neurotic disabilities. It is possible that in a much larger group, including more workers with pronounced neurotic traits such as hypochondriasis, paranoid attitude, insecurity, and gross morbid anxiety, the findings would have been very different. This would also apply to absence from work.

Although domestic and social factors would usually be prominent in causing absence, the small number of persons with poor recent mental health makes it unsafe to draw a conclusion from the fact that recent mental health ratings were, in the most absent group, normal or only slightly below normal. This may in part be explained by the fact that this was a particularly normal group in which the majority of the workers were of long standing. Such a group is the result of active and continuous selection by management, supervisors, and the workers themselves. Thus the assumption that workers who have a psychological handicap such as neurosis often fit badly into industry and produce less than the average worker was not confirmed in this limited study of 80 workers. There was evidence that productivity was affected to a slight extent by general mental ability, the most intelligent producing more than the average, while the least intelligent were among the poorer producers.

Summary

A group of 80 male lead grid casters was studied in an attempt to measure the effect of psychological handicap upon industrial efficiency.

The group of workers were between 22 and 64 years old, with a median age of 37, and had experience of the work varying from a few months to more than 25 years.

The group covered a wide range of intelligence, but the average was lower than that found in a comparable group of soldiers aged 18 to 21 examined by the same test.

Of the two groups of the highest and lowest producers, no great differences in experience or general mental ability were discernible, and the recent mental health of both groups was within normal limits.

The men were grouped into the best and the worst in mental health. With one exception it was found that in the group assessed as worst in mental health the range of productivity was normal with average or fair adjustment to the job. For the best in mental health productivity was slightly below

average but supervisors' ratings tended to be good.

It is suggested that neither psychological handicap nor mental ability affected productivity in all groups so much as social backgrounds in the home and in the factory. Public opinion among the workers tended to settle what should be " average " earnings, and therefore productivity, based on fears of the work being " used up ", resulting in short time in what was a seasonal occupation before 1928.

The smallness and the selection of the group studied made it impossible to regard the findings relating to job-adjustment and to absence with confidence. The group was an élite composed by continuous selection and included few persons with poor recent mental health.

The assumption that workers who have a psychological handicap such as neurosis produce less than the average worker was not confirmed in this limited study of 80 workers. Productivity was slightly affected by general mental ability, the most intelligent producing more than average and the least intelligent being among the poorer producers. Men rated low both for mental health and general ability had an average output and were rated as reasonably well adjusted to the job.

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BOOK REVIEWS

Aspects Nouveaux de la Lutte Contre les Poussières. By L. Dautrebande. (60 text figures, plus 7 colour plates. Belgian Frs 200.–.) Andershem-Bruxelles : Librairie de l'association des Industriels de Belgique.

Professor Dautrebande has been well known for many years on the Continent as an authority on aerosols in the treatment of asthma, and recently he has turned his attention to the subject of dust diseases and their prevention. His numerous publications on this subject are conveniently collected in this book, so that, although it contains no new material, it offers a welcome opportunity of studying and evaluating his views, which have a considerable influence on research policy in France and Belgium.

The first chapter summarizes the evidence for the importance of what the author calls " *les poussières de petite taille* ", but it is difficult, in this chapter, to be sure what are the limits of the range covered by the word " *petite* ". If one takes them to be those commonly accepted in most countries, namely particles of 5 microns in diameter and below, this summary can be considered to be generally excellent and raises few controversial issues. It is, however, clear from the rest of the book, and to some extent from the first chapter itself, that the particles the author considers to be really important are those of 1 micron in diameter and below, although the issue is much confused by the fact that many of the authorities whom the author quotes as referring to the importance of " fine " particles are, in fact, speaking of particles of 5 microns and below. Most of the important properties which Dautrebande attributes to " *poussières microniques et submicroniques* " are shared to a greater or less extent by all particles below 5 microns, and are indeed only different aspects of the same fundamental physical property, a very low terminal velocity, which enables particles in this size range to penetrate to the alveoli and so be retained in the lung. He rightly points out the increased toxicity and penetrating power of " micronic and submicronic particles " but does not mention that these may be offset by their very small size, which means that the actual quantity of material they represent is almost negligible. Clearly, it is not sufficient to show that a certain weight of submicronic particles is much more effective than an equal weight of, say, 5 micron particles if, in fact, in all ordinary conditions the weight of submicronic particles is actually only a few per cent. of all those below 5 microns. The importance of this consideration is shown by the fact that the author is unable to quote any convincing instance from actual experience to show that micronic and submicronic particles are, in fact, of predominant importance, although he makes many attempts to do so ; for instance, he claims that wet drilling is always ineffective, owing to the ability of very fine particles to escape suppression by water, and quotes as evidence statements by Dreesen and others that, in spite of wet drilling having been legally obligatory for 20 years, silicosis was not suppressed in the mines of Utah. He does not, however, mention that dust sampling, carried out with the impinger, showed that there were sufficient dust particles, inside the ordinary range of 1 to 5 microns, present in the air to account for the development of silicosis. The authors, in fact, commented in their paper that the wet drilling was ineffective for technical reasons, and in addition it can be presumed that it was not necessarily always regularly used just because it was legally required. Similarly, Dautrebande claims that, in spite of the use of wet drilling in South Africa since 1910, silicosis is still occurring on the Rand. But in the days before wet drilling and other dust suppression methods were introduced, the expectation of life of an average South African gold miner was eight years, whereas now the average time taken to reach the very earliest radiological stage of silicosis is 18 years. This enormous reduction in the disease runs parallel to a reduction in the number of dust particles in the air as shown by the konimeter, which does not collect particles efficiently below 1 micron in size. Another example quoted by Dautrebande is a paper on vanadium poisoning by Williams, which he claims showed that only the particles less than 1 micron in diameter were important. Reference to the paper, however, reveals that Dautrebande's statement, " It is however certain that the respiratory symptoms of vanadium poisoning were due to the numerous particles of small size ", is his own and is not made by Williams. In fact, since the symptoms of vanadium poisoning were acute and mainly upper respiratory, it is probable that they were at least as much due to the coarser particles as to the fine. Another example of his somewhat dubious use of other workers' observations is the statement he attributes to Brown and Schrenk that particles of 2 microns and below are not suppressed by water " screens ". Reference to the paper cited in the bibliography shows no such statement, but only a general observation that sprays of water were less effective for fine particles than for coarse.

The second chapter of the book is concerned with methods of collecting and examining dust. The only criterion which the author regards as important in the classification of sampling instruments is their ability or otherwise to retain submicronic particles ; he appears to attach no importance to being able to study a sample of dust in the air in its original state, neither dispersed in liquid nor caked on a filter. He speaks respectfully

of the thermal precipitator, since it is the only instrument at present in use which is capable of capturing efficiently particles of less than 1 micron in diameter, but does not appear to be aware of the fact that, in Great Britain at any rate, it has been found necessary for many years to ignore the particles of less than 0·5 micron in diameter, in order to be able to get a stable result. He does not himself set any lower limit to the size of particle he would consider important, and appears to be quite unaware of the fact that by this omission he makes it impossible for any results to be quoted. He himself puts forward as a solution to the sampling problem an instrument called the " midget-scrubber D.18 ", which is a modification of the impinger and which he claims to be capable of capturing particles down to 0·1 micron with complete efficiency. The only evidence for this claim that he presents is that when two of the instruments are used in series the quantity of dust found in the second instrument is " inappreciable ". This is clearly a potentially fallacious test, since the physical principles involved in the capture of dust by an instrument of this kind are such that it is to be expected that the particles which will escape the first instrument will also largely escape the second. The critical experiment of sampling the effluent from a " midget-scrubber " with a thermal precipitator has yet to be done, but some clue to the result can be gained from the fact that the author himself, in a later chapter, illustrates the use of a midget-scrubber as an aerosol generator, and it is, in fact, commonly used for this purpose in laboratories where Dautrebande's work is being studied.

Dautrebande also repeatedly refers to the importance of being able to carry out a size analysis on dust samples, but does not explain how the problem of overcoming the great amount of labour involved is to be solved in routine sampling. He is evidently unaware of the valuable work of Bedford and Warner (1943), and Wynn and Dawes (1951), who have shown that, at least in coal mines, the size analysis of air-borne dust within the respiratory size range tends to be sufficiently constant for it to be possible to use the weight, surface, or number of the particles within a limited size range as interchangeable measures of quantity. The author disregards the physical principles involved in dust inhalation when he proposes to carry out his size analyses on samples of dust dispersed in liquid. The importance of a size analysis is mainly the influence of particle size on penetration into the respiratory tract, and the size that matters in this respect is the actual size of the particle or aggregate as it exists in the air. In practically all industrial dust clouds the larger particles are aggregates which will be dispersed in a liquid, especially in an instrument such as the midget-scrubber, so that it will be impossible to determine the true size analysis of the air-borne dust. An even more serious criticism of the midget-scrubber, however, is that it shares with the impinger the fundamental defect of not eliminating air-borne particles and aggregates which are too large to penetrate to the alveoli. Such particles and aggregates are collected by it and are then dispersed and contribute to the total count, as shown by Houberechts and others (1952) for the impinger ; this count correlates better with the total weight of dust in the air than with the number of particles in the respirable size range, determined by the thermal precipitator.

The next chapter deals with the author's suggested method of suppressing dust by agglutinating it with a sodium chloride aerosol. The evidence he adduces for the existence of this agglutination phenomenon is convincing, but it appears clear that the method will only work, if at all, in conditions of high dust concentration and poor ventilation, and it requires an equal, if not greater, concentration of aerosol ; to such a level, in fact, that, as the author says, the aerosol will be easily visible. The author attempts to support his idea by means of elaborate and prolonged animal experimentation, the results of which are beautifully illustrated with colour photomicrographs, but which he himself evidently feels are somewhat unconvincing. Although the quantity of dust found in the lungs of animals exposed to a cloud of silica dust mixed with a sodium chloride aerosol, is, on the average, only half that of animals exposed to a silica cloud alone, the observation is rendered somewhat doubtful by the fact that the quantity of dust found in the lungs of both groups of animals is not correlated in any way with the period of their exposure to dust. Nevertheless, the author concludes that the results of the experiment are such that the same principles should " logically " be applied to industries where there is a silica risk. He does not, however, deal with the many obvious and serious practical objections to such a plan. For instance, the size and weight of the numerous aerosol generators required, together with the volume of sodium chloride solution ; the fact that the method can only hope to work at all in conditions of poor ventilation, and the undoubtedly serious effects of an atmosphere charged with sodium chloride on machinery of all kinds. Moreover, even if one could attribute a reduction of 50% in dust concentration to a sodium chloride aerosol, a very much greater reduction could easily be achieved by the use of ventilation and such a method would undoubtedly be preferable.

It is curious also that Dautrebande does not refer to the work described by Houberechts and Ledent, carried out at his instigation at Glain-lez-Liège. In this experiment, two groups of rabbits were exposed to natural and artificial clouds of dust with and without the addition of sodium chloride aerosols. Large numbers of dust samples were taken with various instruments and showed that, if anything, the concentration of dust particles between 1 and 5μ was higher in the presence of a sodium chloride aerosol than without it. Moreover, the pathological report on the rabbits states flatly. " The object of the experiments was not attained. It cannot be stated that the subjects of the experiments who were subjected to siliceous or non-siliceous dusty atmospheres for varying periods of 6, 11, and 27 months, were noticeably benefited by the addition to the dusty air current of the aerosol under test."

The next chapter of the book deals with the use of " pneumodilating " aerosols such as " aleudrin ", the

virtues of which the author has been advocating for many years. He is evidently unaware of the work of Lewis-Faning on the variability of response to aerosol treatment and few would agree that he has made a convincing case for his suggestion that aerosols should be used daily by all workers in dusty industries.

The author also claims to have shown that immediate bronchospasm is produced by the inhalation of dust ; it would be interesting to have these observations repeated by independent workers.

In conclusion, the author summarizes the previous chapters, and again stresses the predominant importance of micronic and submicronic particles, the difficulty of suppressing them, and the consequent desirability of augmenting their size by means of a sodium chloride aerosol. This chapter, like the whole book, is most skilfully and persuasively written, in a style reminiscent of the late George Bernard Shaw, and it is not at all surprising that the author's writings have such a powerful influence.

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In the past decade or so there has been built up by the physical sciences a substantial store of knowledge which is more and more being applied to the study and reduction of atmospheric pollution. Much of the work done in the United States has been carried out by civil and military departments of the Federal Government, and it seemed that in the public interest as much as possible of the information should be made generally available. Informal meetings took place between representatives of the several departments concerned, and it was agreed that a conference should be convened to meet in Washington in May, 1950. It was also agreed that outstanding workers in related subjects should be invited from the universities, research foundations, and industry. The President of the United States formally authorized the setting up of an interdepartmental committee to sponsor the conference and make the proceedings available to the public.

The conference was divided into seven panels dealing with agriculture, analytical methods and properties, equipment, health, instrumentation, legislation, and meteorology.

The first 33 pages of this large volume contain accounts of the general sessions of the conference at which the panel chairmen gave brief surveys of the work of their panels, and the rest of the volume consists of the papers presented at the conference. Some of these are quite short while others give greater detail. There are 97 separate papers, so that none could be long if the proceedings were to be published in a single volume.

The 14 papers given before the Agriculture Panel dealt with the effects of atmospheric pollution on vegetation and on livestock. Pollution by fluorine and fluorides figures largely in these papers.

Those concerned with industrial hygiene will be much interested in some of the 14 papers on analytical methods and properties. These are interesting accounts of the behaviour and properties of air contaminants and of aerosols, of particle size in relation to air pollution, of the application of the electron microscope to air pollution, and of the use and limitations of the midget impinger. Papers on analytical methods deal with fluorometric analysis, colorimetric methods, spectrometric analysis, infra-red spectroscopy, and the identification and estimation of gases and vapours in air pollution.

Twenty-four papers deal with equipment. One of them describes methods of odour control and another the catalytic combustion of hydrocarbon vapours. Various papers are concerned with filters of various types—dry, viscous, cloth—and with the characteristics of filter beds. Spray towers and spray scrubbers are the subject of other papers. Dust collectors of various types, dynamic, condensation, electric precipitation, sonic flocculation are discussed, some of them from the standpoint of fundamental principles. Yet other papers deal with smoke-abatement equipment.

The Health Panel had 14 papers. One dealt with short exposure to high concentrations of air pollutants, and another with prolonged exposures. These were papers concerned with the effects of exposure to the general pollution of the air of towns, including one on the Donora, Pennsylvania, incident. Another dealt with the effects of " inert " dusts, another with the effects of air pollution on cancer hazards Yet another dealt with the effects of loss of sunlight on health.

The 14 papers presented to the Instrumentation Panel were concerned with the sampling and determination of aerosols and with various methods of measuring atmospheric pollution, including some on the measurement and recording of sulphur dioxide and sulphuretted hydrogen.

The nine papers to the Legislation Panel included one on legal aspects of atmospheric pollution and methods of control used in Great Britain. The remainder were concerned with American requirements and problems.

Finally, there were eight papers on meteorology in relation to atmospheric pollution. Here the results of British work on diffusion and on the dispersion of hot gases in the atmosphere took a prominent place.

This appearance of this volume is an important event in the study of atmospheric pollution, whether as it affects the public health officer, or those concerned with health in industry. The contributors include the most prominent workers in the United States and some from Great Britain, and their collected papers form a mine of information which will be of enormous help to workers in various fields of research, and to those in many industries whose duty it is to prevent or reduce the escape of noxious materials into the atmosphere.

THOMAS BEDFORD

Human Nature : Its Development, Variations and Assessment. By John C. Raven. (Pp. xii + 226. 12*s.* 6*d.*) London : H. K. Lewis. 1952.

An introduction to the study of psychology today may easily be complicated by the growing confusion of schools and jargons. The semantic problems of the student are becoming more difficult with the increasing contributions of clinicians and sociologists and transatlantic social scientists, all with their own technical language and discipline. At the same time there is a growing demand that everyone whose job is even remotely concerned with people should make some study of psychology and that this should begin at an early stage in training.

In this introduction to individual and social psychology Dr. Raven neatly avoids this confusion, and the resulting book is clear and concise. It contains no jargon at all, and the few technical terms which are used are well and fully defined. Moreover, the author is careful to present only what is by now generally agreed upon, and he omits all but passing reference to the controversial.

There are three main sections, of which the first describes the development of behaviour from infancy to maturity ; the second some variations in the experience of the adult ; and the last the assessment of individual abilities and interests. There is in addition a brief statistical appendix and a glossary of the terms used. To begin with, the place of psychology in the study of behaviour and its methods of approach are explained. The growth of the child, intellectual, social, and emotional, is then described and his acquisition of social skills discussed. The effect of the family group and the emotional events of infancy and adolescence are clearly outlined but are perhaps not given as much attention as they deserve. In consequence, the section may fail to impress upon the reader the fact that these early years are now generally regarded as of paramount importance in the formation of personality. In the part which deals with adult experience the author is clearly talking to another more mature audience, and his section on introspective and social psychology is a very helpful introduction to the subject. Dr. Raven comes into his own in the last section on mental testing. It is the best part of the book, probably because of his undisputed authority in this field. His description of the uses, and more particularly of the abuses, of mental tests in selection procedures will be of particular interest to industrial medical officers who are often consulted upon the value of such tests.

So much learning is compressed into this small volume that some aspects of the subject are bound to be neglected as a result. For instance, the inclusion of the whole of biological evolution into the first few pages is probably unnecessary, being too brief for those unacquainted with the subject. Moreover, because of its lack of controversial matter and perhaps because it is obviously a summary of a series of lectures, the style of the book is detached and leaves us with the feeling that here we shall not find answers to the problems of behaviour, but rather a very competent description of what happens.

There can be few people who served in H.M. Forces during World War II who were not tested at some time by one of Dr. Raven's tests, or by a test which derived from them. Clear thinking was needed for the construction of such tests, and clear thinking has gone into this little book. As an easy introduction to the subject for students, it will be very useful.

E. MAURICE BACKETT

Employment Problems of Disabled Youth in Glasgow. By T. Ferguson, A. N. MacPhail, and M. I. McVean. (Pp. 66 ; 3*s.*) Medical Research Council Memorandum No. 28. London : H.M. Stationery Office. 1952.

" There can be few more promising fields for the practice of constructive medicine than those concerned with the problems of disabled youth." So starts this fascinating report based on a study of the employment experience of two groups of Glasgow young people. The first consisted of 579 young people who were registered under the Disabled Persons (Employment) Act, 1944, the second of 408 who had left schools for physically handicapped children during the years 1945–48. The investigation was directed at finding out to what extent disabled young folk are unable to earn a living, what kinds of disability interfere most seriously with their working capacity, how far social and environmental factors contribute to their difficulties, and whether any remedial actions suggest themselves. The two groups were studied separately, not being strictly comparable, but the findings are similar and corroborative.

Of the two groups combined, 19% were unemployed at the date of the survey, 20·5% were engaged in office or other non-manual work, 32·5% in skilled or semi-skilled manual work, 27% in unskilled manual work, and 1% in unclassified manual work. Compared with a group of ordinary ex-school boys aged 17, the amount of unemployment and the proportion engaged in unskilled manual work is much higher in the disabled group. The vicious circle of illness or injury, loss of schooling, unskilled, often heavy, work, and further illness is illustrated, and it is evident that many disabled young people, often driven by necessity, are doing work far beyond their physical capacity. Among factors which adversely affect chances of a suitable employment one of the most important is shown to be lack of schooling, and this aspect is stressed throughout the report. In regard to the type of disability, those with conditions affecting the nervous system and the mentally handicapped form a very difficult problem. Social factors, though complex and difficult to assess, are dealt with adequately and are shown to play an important part. No less than 113 of the 579 registered persons lived in homes that could only be described as appalling. The chances of home study during apprenticeship or while attending night classes are nil under such conditions. Unemployment of the father or apathy in the parents adversely affect the chances of gaining and keeping a satisfactory job while death of the father often drives the young person to work which is, though perhaps well paid, too heavy and merely temporary.

This report succeeds in being a human document in spite of its 59 tables. The results are clearly set down and

interspersed with many examples which vividly illustrate the conditions found and the administrative problems involved. There are brought to light many unforeseen ways in which an apparently simple measure such as the Disabled Persons (Employment) Act, 1944, can be complicated in practice by human and environmental factors. Much depends on flexible and imaginative administration. Apart from improving basic living conditions the authors suggest four lines of action: mitigation of the gross lack of education, adoption of energetic action to secure satisfactory settlement immediately after leaving school (as otherwise " the hopes of 14 turn into the cynicism of 21 "), remedy of the present serious lack of training courses for disabled young people, and intensive medical and surgical treatment, including the provision of necessary aid and appliances.

There are several references to the very excellent work of the Glasgow Outdoor Mission to the Deaf, a voluntary body, and the suggestion is made that similar success might be attained in other disabilities if the same deep insight and interest were shown.

A short account is given of the work of the Danish Invalidity Court from which it is inferred that vocational training for disabled young persons is more widely practised in Denmark than in this country.

A. S. DOIG

Slough Industrial Health Service. Fifth Annual Report for 1951-52. By A. Austin Eagger, with Foreword by Sir Noel Mobbs. (Pp. 39. 2*s*.) 1952.

This is not only a report for the year 1951–52, but also an account of the development of the Service during its first five years. The scheme has expanded from serving 52 member firms in 1947 to 143 with 15,175 employees today, but there are still some 150 factories which have not joined the Service.

For this lack of interest among some managements and workers, Dr. Eagger suggests the reasons may be economic, an impression that industrial health services are a State responsibility, or simply apathy.

The experimental nature of the original plan is stressed. Certain facilities had to be provided to ascertain their value. With this experience and the need for economy, it has been both necessary and possible to modify the original plan but still to provide for essentials.

The report deals with various aspects of the Service in some detail. The Occupational Hygiene Team, which was formed jointly with the Occupational Health Unit of the London School of Hygiene and Tropical Medicine, has been doing valuable field work in the detection and control of toxic hazards for the member firms, and also for outside bodies through enquiries submitted to the School of Hygiene.

The Casualty Service has not changed its form to any great extent over the five years, though a hand clinic has recently been introduced.

The Physiotherapy Department's work has increased each year, and in the year under review 31,089 treatments were given to 4,084 patients. Patients are referred not only by the Service, but also by the staffs of local hospitals and general practitioners.

The Social Service Department is a recent innovation. The social service officer deals with many medico-social problems which are referred by the medical officers or by the management of firms. This has been shown to be valuable in an area where many of the firms are so small that they have no welfare service of their own.

Farnham Park Recuperative Centre is an integral part of the Service with accommodation for 66 in-patients and 20 out-patients. In five years 2,432 men and women have been treated here. There are full facilities for occupational therapy, physiotherapy, and remedial gymnastics, with a balanced programme of education and recreation. The facilities provided by the social service department are particularly valuable in this centre. There is close cooperation with the Government Training Centre in the rehabilitation and assessment of patients.

The statistical report gives a general picture of the amount and type of work done in the various clinics and departments, and of the types of defects found at medical examinations. It is unfortunate that progressive simplification of the records system on the grounds of economy has prevented comparison of the statistics for more than the past three years. It is also a pity that it has not been possible to present comprehensive morbidity statistics for all this large industrial population, but the multiplicity of organizations obviously make this difficult.

The report shows that the sponsors, council of management, and staff can be well satisfied with their achievements in this important experiment. However, its financial position is not very healthy. During 1951–52 there was a deficit of about £3,500 and there is an overdraft of £12,778. The Nuffield Provincial Hospitals Trust is now only supporting the Occupational Hygiene Team. The North-West Metropolitan Regional Hospital Board contributes two-thirds of the total cost of the Service. This meets a large proportion of the cost of the work carried out at the Recuperative Centre and in the therapeutic clinics.

From the accounts it is not possible to get more than a rough estimate of the cost of the preventive and casualty part of the services as opposed to the therapeutic services, which are really provided on behalf of the National Health Service.

However, the report will be of value to all those who are interested in the development of a comprehensive occupational health service.

A. RAFFLE

Biological Hazards of Atomic Energy. Edited by A. Haddow. (Pp. 225 plus index; illustrated. 35*s*. net.) Oxford University Press (London: Geoffrey Cumberlege). 1952.

What are the dangers in exposure to ionizing radiations? How can they be minimized? These questions were considered at a conference sponsored jointly by the Institute of Biology and the Atomic Scientists Association in October, 1950, the proceedings of which are reported

in this volume. The conference, the first of its kind in this country, saw the gathering together of a group of distinguished contributors, each one an expert in his own special subject. The more spectacular events in the development of atomic physics for scientific, industrial, and medical purposes are well known but the diverse and rapidly widening applications of all this new knowledge, already affecting the lives of large numbers of people, are probably not generally realized. Those who are responsible for health and safety must see to it that progress in this field, implying as it must, a continuing increase in the number of people regularly exposed to radiation, is not accompanied by increased risks to the health of those concerned.

The first set of papers deals with the many and various ways in which living cells may respond to exposure to ionizing radiations. These effects depend on the physiological condition of the cell, on the duration of exposure, and on the type or quality of the radiation.

The long-term hazard of atomic energy is discussed in detail by a group of eminent geneticists and the reader is left in no doubt that small amounts of radiation exposure, apparently innocuous to the individual, may result, nevertheless, in the impairment of future generations.

The principles of protection are considered. There is an interesting description of the methods of estimating so-called tolerance levels. A number of specialists in protection relate their experiences in hospitals and research laboratories. At the Harwell Atomic Energy Research Establishment it has been possible to provide adequate control over all types of radiation hazard but the cost of complete protection is great and it is necessary to find a balance between economy and safety.

Although the majority of the papers in this volume are concerned, in the main, with the effects of irradiation of the body from the outside, the rather different problems which occur when radioactive substances are introduced into the body are discussed briefly. The possibilities of protection against massive doses of ionizing radiation are examined; at present no effective method is available.

It is appropriate that the final contributors to the discussions are concerned explicitly with the moral issues which appear to be especially relevant to this subject.

Here, then, is an authoritative and balanced statement of the position in this vital field. Although the matter contained in many of the contributions is of a quality which demands a certain amount of scientific knowledge for its complete understanding, any reader will be able to form a useful picture of the biological problems which arise in connexion with atomic energy.

A. McLEAN

The Medical Research Council: Opportunities for Appointment to the Scientific Staff. (Pp. 19.) Obtained on request from the Establishment Officer, Medical Research Council, 38, Old Queen Street, London, S.W.1.

This booklet gives a brief account of the constitution and field of work of the Medical Research Council, which now has 45 research establishments. Most of them are based on hospitals and universities, although its largest and probably best known establishment is the National Institute for Medical Research at Mill Hill, London. The Council is not constitutionally a government department since it administers grants-in-aid provided annually by Parliament, and selects and appoints its own staff. Its policy is to offer the members of its scientific staff, who may be medically qualified or otherwise, careers and salaries which are as good as those offered to the holders of appointments of similar status in the universities. The Council leaves it to the director of a unit or research group to recommend suitable persons for appointment to the staff. Thus prospective candidates should apply to the director of the establishment at which they would like to work.

The booklet gives terms of service and conditions of work of its staff and also information about scholarships, fellowships, and grants, which may be awarded by the Council.

One of its most useful contents is a list of research establishments with addresses and names of directors. There are at least 11 research units or groups doing occupational health research.

RICHARD SCHILLING

BOOKS RECEIVED

(Review in a later issue is not precluded by notice here of books recently received.)

How to Use a Medical Library: A Guide for Practitioners, Research Works and Students. 2nd ed. By Leslie T. Morton. (Pp. vii + 40 + index. 5*s*.) London: William Heinemann. 1952.

Praktische Arbeitsphysiologie. By Gunther Lehmann. (Pp. 352; with 145 text figures. DM. 29.70.) Stuttgart: Georg Thieme Verlag. 1953.

The National Corporation for the Care of Old People. Fifth Annual Report for the Year Ended 30th April, 1952. (Pp. 35.) London: National Corporation for the Care of Old People. 1953.

Fundamentals of Clinical Orthopedics. By Peter A. Casagrande and Harold M. Frost, Jr. (Pp. 582; with 390 text figures. $18.50). New York: Grune & Stratton, Inc. 1953.

The National Health Service. Edited by Max Sorsby, with a Foreword by Sir Allen Daley. (Pp. 267. 12*s*. 6*d*.) Edinburgh: E. & S. Livingstone. 1953.

ABSTRACTS

(This section of the JOURNAL *is published in collaboration with the two abstracting Journals,* Abstracts of World Medicine, *and* Abstracts of World Surgery, Obstetrics, and Gynaecology, *published by the British Medical Association. The abstracts are divided into the following sections : toxicology ; industrial physiology ; industrial lung disease ; industrial skin diseases ; accidents and orthopaedic surgery ; industrial ophthalmology ; environment ; general. Not all sections will necessarily be represented in any one issue)*

INDUSTRIAL TOXICOLOGY

Effects of Dimethyl and Diethyl *para*Nitrophenyl Thiophosphate on Experimental Animals. DIECHMANN, W. B., PUGLIESE, W., and CASSIDY, J. (1952). *Arch. industr. Hyg. occup. Med.*, **5**, 44.

Both the diethyl and dimethyl esters of thiophosphoric acid are now extensively used as insecticides. The former was known to have an effect similar to that of drugs having a cholinergic action. The possible toxicity of the dimethyl derivative was therefore investigated. It is concluded that the safety measures required in the use of parathion (diethyl *p*-nitrophenyl thiophosphate) should be applied with equal vigour in the use of dimethyl *p*-nitrophenyl thiophosphate, although the latter compound is less toxic by one-fifth to one-half than parathion.

M. A. Dobbin Crawford.

Physiological Response of Experimental Animals to the Vapor of 2-Nitropropane. TREON, J. F., and DUTRA, F. R. (1952). *Arch. industr. Hyg. occup. Med.*, **5**, 52.

The hazards attending the use of 2-nitropropane, a nitroparaffin used as a commercial solvent, were investigated in experimental animals. Cats, rats, rabbits, and guinea-pigs, in that order, were found decreasingly susceptible to intoxication by the vapour. All survived repeated 7-hour exposures to an atmosphere containing 2-nitropropane in a concentration of 0·297 mg. per litre, or 83 parts per million (p.p.m.), the animals being exposed on 5 days a week for 26 weeks. All the animals except the cats survived similar exposure to an atmosphere containing 328 p.p.m. The minimum lethal dose for cats was 1 hour's exposure to 2,353 p.p.m., or 2·25 hours' exposure to 1,148 p.p.m., or 4·5 hours' exposure to 714 p.p.m.

Lethargy and feebleness developed, proceeding to a state of prostration with dyspnoea, cyanosis, occasional convulsions, and ending in coma and death. Lacrimation, salivation, and gastric regurgitation were noted in cats only. Those animals surviving for some hours lost weight, methaemoglobin and Heinz bodies were formed in the blood, and the clotting time was prolonged. Cats dying after several repeated exposures to a concentration of 328 p.p.m. showed severe parenchymal degeneration and focal necrosis of the liver, with a moderate or slight toxic degeneration of the heart and the kidneys ; there were also haemorrhages into the alveoli of the lungs with oedema of the lung tissues and interstitial pneumonitis. Severe acute poisoning caused general injury to the endothelium of the blood vessels throughout the body, with pulmonary haemorrhage, selective disintegration of the neurones of the brain, and liver damage.

A concentration of 0·18 mg. per litre (50 p.p.m.) is suggested as the maximum allowable for a working day. [This agrees with the ruling of the American Conference of Governmental Industrial Hygienists, but is double that recommended by other authorities.]

M. A. Dobbin Crawford.

Toxicity of Sulfuric Acid Mist to Guinea Pigs. AMDUR, M. O., SCHULZ, R. Z., and DRINKER, P. (1952). *Arch. industr. Hyg. occup. Med.*, **5**, 318.

A quantitative study was made at Harvard University School of Public Health of the toxicity of low concentrations of sulphuric acid mist to guinea-pigs. The period of exposure varied between 8 and 72 hours, and the concentration of acid between 8 mg. and over 50 mg. per cubic metre ; the mean particle size was 1 μ. Full details are given of the apparatus used to produce the mist [for which the original should be consulted]. Concentrations up to 0·24 mg. per cubic metre have been reported in the Los Angeles " smog " area and are to be expected occasionally in industrial communities burning soft coal. Guinea-pigs were used as they are more susceptible to sulphuric acid than other laboratory animals, two groups, of different ages, being studied separately. All the animals survived a concentration of 8 mg. per cubic metre. The LD50 for the older animals was 50 mg. per cubic metre, for the younger animals 18 mg. per cubic metre. It was found that sulphuric acid produces two distinct and different toxic actions. The animals which died almost all succumbed to laryngeal spasm. Those which survived the initial exposure were killed about 3 weeks later, when deep-seated lung damage was still present. The spasm-producing action depended on the concentration of acid and not on the length of exposure, whereas the extent of lung damage depended on the total exposure, that is, the product of concentration and time of exposure. Lung damage consisted of pneumonic changes, haemorrhages, thickening of the alveolar walls, atelectasis, and congestion of the alveolar spaces. It is concluded that inhalation of sulphuric acid in the concentrations used may produce more severe and lasting lung damage than has previously been thought.

Leslie G. Norman.

Hematological Investigation on Workers Exposed to Mercury Vapour. KESIC, V. B., and HAEUSLER, V. (1951). *Industr. Med. and Surg.*, **20**, 485.

Observation over a period of years in Yugoslavia of patients suffering from chronic mercurialism failed to disclose any noteworthy alterations in their blood elements or haemoglobin. Blood examinations were then undertaken, in Idria, on 130 mercury miners, on 59 workers employed in the mercury-smelting plant, and on 70 women workers in a felt-hat factory. To serve as a control 202 metal-industry workers and 264 women employed in the textile industry were also examined. No fewer than 71 of the mercury miners and smelters and 47 of the felt-hat workers showed frank symptoms of chronic mercury intoxication. The concentration of mercury vapour in the working atmosphere was high ; in the mine it varied between 1·2 and 5·9 mg. per c. metre of air. (Maximum atmospheric concentration = 0·1 mg. per c. metre.) The results, which are presented in detail in tabular form, show no significant differences between the blood counts of the exposed workers and those of the control subjects. The estimation of haemoglobin, colorimetric and photometric, yielded less definite results, for the readings showed much variation. In a few of the exposed workers the readings were high —over 100%. It is pointed out that in relation to haemoglobin values there are many other factors which should be considered.

No conclusions can be drawn from these small numbers, but investigations are continuing.

[The bibliography contains a brief quotation from each author referred to.] *M. A. Dobbin Crawford.*

Eye Changes following Exposure to Metallic Mercury. LOCKET, S., and NAZROO, I. A. (1952). *Lancet*, **1**, 528.

Among 51 repairers of direct-current electric meters who handled metallic mercury and were examined for eye changes, 12 showed a matt-brown reflex from the anterior lens capsule. This change seems to depend mainly on length of exposure to metallic mercury, and is not related to symptoms of mercury intoxication at the time of examination. In all cases this brown reflex was bilateral and apparently had no effect on visual acuity. No evidence of retrobulbar neuritis was found in any of the 51 workers examined. It is suggested that this coloured reflex from the lens could be used as a screening device for atmospheric mercury levels.—(Authors' summary.)

INDUSTRIAL LUNG DISEASES

Tuberculosis in Anthracosilicosis. THEODOS, P. A., and GORDON, B. *Amer. Rev. Tuberc.*, **65**, 24.

This is a study from Jefferson Medical College Hospital, Philadelphia, of 750 cases of anthracosilicosis occurring in anthracite miners in Pennsylvania. Of this number 12·9% had sputum positive for tubercle bacilli ; the inclusion of cases with healed tuberculous lesions and cases suspected on clinical or radiological grounds but sputum-negative raised the total classified as anthracosilicosis with tuberculosis to 14·9%. Tuberculosis was found most frequently in miners who had been exposed to dust for 20 to 40 years, the highest incidence (75%) being in the fourth and fifth decades of life. It was eight times as common at age 35 to 44, and three times as common at age 45 to 54, as in a comparable group of workers in other industries.

The percentage incidence of symptoms and signs is given, and the radiological findings are discussed. Of 244 cases showing "conglomerate" opacities tuberculosis was diagnosed in only 11·5% ; of 320 cases showing asymmetrical shadows only 25·9% proved to be tuberculous. Only 25% of the cases showing deviation of the trachea proved to be tuberculous. Tuberculosis was found most commonly in association with third-stage silicosis. The question whether the tuberculosis studied was a reactivation of disease existing before exposure to silica or a new infection is discussed.

The life-expectation for cases treated at home was up to 3 years from time of diagnosis, and probably one year longer with hospital care. Tuberculosis occurring with nodular silicosis was thought to have a somewhat better prognosis than that occurring with massive fibrosis. The scope of treatment is limited, and is mainly symptomatic.

[It is not fully clear that the authors have appreciated that the relationship between anthracosilicosis and tuberculosis may be different from that between "pure" silicosis and tuberculosis.] *L. W. Hale.*

A Contribution to the Study of the Risk of Silicosis in Foundries. UYTDENHOEF, A. (1951). *Arch. belges Méd. soc.*, **9**, 357.

The author describes a study, made by the Medical Inspectorate of the Belgian Ministry of Labour, of the risk of contracting silicosis in iron and steel foundries. The various types of foundry work are described and the results given of dust counts made with an Owens jet dust counter in samples of air taken from different situations in a foundry. Dust extracted from the air and dust deposited in various parts of the foundry were also chemically analysed and in both cases were found to contain a considerable percentage of silica and iron. At the same time, 302 foundry workers from 58 different factories were examined radiologically, of whom 65 showed radiological evidence of silicotic fibrosis. In 47 of these cases there was accentuation of the lung markings with infrequent small nodules, in 17 generalized small nodules in addition, and in one definite nodulation. This last was in a man of 49 who had been a planer for 22 years. Most of the affected workmen were moulders, but a few were cupola men, grinders, polishers, planers, and general labourers.

The author concludes that all foundry workers run the risk of developing silicosis and that they should all, therefore, be eligible for industrial compensation in respect of this condition.

[It is difficult in the absence of radiographic illustration to compare these findings with those of other workers.

The figure of 15% in the first stage agrees closely with the 17% of foundry workers found by McLaughlin and others (*Industrial Lung Diseases of Iron and Steel Foundry Workers*, London, 1950) to have fibrosis. The Belgian study confirms the main finding of the above report, namely, that all workers in iron and steel foundries run the risk of contracting silicosis.] *John Pemberton.*

Silicatosis of a Micronodular Type among Women Employed in Glaze Spraying on Metal Objects. TROISI, F. M. (1952). *Indust Med. & Surg.*, **21**, 47.

The author describes 4 cases in which radiological abnormalities were discovered in the lungs of women exposed to enamel dust containing only 1 to 2% free silica, the rest being silicates. There was no disability. It is concluded that silicates are capable of producing pulmonary fibrosis, the radiographs being described as showing reticulation with micronodulation. [Reproductions of the radiographs are given, but are too small to show the precise nature of the abnormalities.] *C. M. Fletcher.*

GENERAL

The Effect of Silicosis on the Cardiovascular System. CREPET, M., PALU, C. D., and GARGANO, G. (1951). *Arch. Inst. cardiol. Mex.*, **21**, 178.

The effect of silicosis on the cardiovascular system has been assessed in 350 patients, who were classified in 3 stages : 96 had " early " disease and 142 had " advanced " disease. The methods of study included clinical and electrocardiographic examinations and estimation of effort tolerance, circulation time, and venous pressure. The results confirm those of other workers that cardiac involvement occurs only in the advanced stages of the disease, except that the incidence of cor pulmonale was less than that usually found. *A. J. Thomas.*

Acoustic Trauma in Aircraft Maintenance Workers. GUILD, E. (1951). *J. Aviat. Med.*, **22**, 477.

Pure-tone audiograms for 11 different frequencies were determined in the following 4 groups of workers : mechanics concerned with conventional-type aircraft, mechanics dealing with jet engines, pilots with considerable flying experience, and personnel experiencing engine noise only as a background. Air-conduction studies were supplemented by bone-conduction studies in those subjects showing significant loss of acuity. The groups were roughly similar in size, age distribution, and duration of exposure, except that few pilots were less than 30 years of age.

For subjects below the age of 25 there was little over-all difference between the groups. At intermediate ages all groups showed diminished acuity to the higher frequencies, but the 2 groups of mechanics had a lower average auditory acuity than the normal, and this loss was more marked in mechanics and pilots working with jet engines than in those dealing with conventional-type aircraft. The differences tended to disappear with increasing age, but defects appeared earlier and were more marked in those subjected to noise. Subjects over 34 exhibited a comparable loss of acuity in all groups.

It is concluded that definite impairment of hearing may result from exposure to engine noise, and that jet engines impose a greater hazard than do conventional types. The marked loss of acuity found in the group of pilots might be due to their greater average age and to their longer exposure to noise. *P. Howard.*

A Portable Ultramicroscope for the Determination of the Concentration of Submicroscopic Particles in the Air of Industrial Undertakings. BELKIN, E. S., and KOSENKO, A. (1951). *Gigiena* No. 8, 50.

For the ultramicroscopical estimation of dust particles of minute size in air the authors have made a portable apparatus in which the tube of the microscope passes through a hole in a closed box. Light from a lamp totally enclosed in a separate chamber of the box passes through a lens system and condenser to illuminate from the side a tube through which the contaminated air is passed below the microscope in such a way that it cannot deposit any dust in the box itself. By adjusting a diaphragm it is possible to arrange that at any one time no more than 4 or 5 dust particles appear in the field and can be counted before the current of air has passed on. [The apparatus would appear to be both convenient and effective.] *G. C. Pether.*

" Back to Work ". The Industrial Rehabilitation Units of the Ministry of Labour and National Service. JONES, J. A. L. VAUGHAN (1951). *Brit. med. J.*, **2**, 601.

The function of rehabilitation is " to restore the worker to industry, the citizen to society, and the man to himself ". There should be no clear-cut dividing line between medical and industrial rehabilitation, nor between industrial rehabilitation and resettlement. A residential industrial rehabilitation unit was set up at Egham, Surrey, in 1944, and since then other non-residential units have been set up at Birmingham, Bristol, Cardiff, Coventry, Edinburgh, Felling-on-Tyne, Glasgow, Hull, Leeds, Leicester, Long Eaton, Manchester, and Sheffield. Each caters for about 100 inmates, and their object is to restore the fitness of persons suffering from physical and mental disabilities which handicap them in getting and maintaining employment, to discover by observations and with medical advice the personal factors which may be impeding satisfactory settlement in employment, and the types of employment most likely to lead to permanent settlement.

Any person over the age of 16 is eligible to apply for a course of 12 weeks' duration, during which maintenance allowances are paid according to family circumstances. The facilities of these units include a gymnasium, workshops, and gardens, and these are used as necessary to meet the needs of each individual undergoing the course, which is under the direction of a medical officer, a vocational officer, an occupational supervisor, and a social worker. There have been 21,771 entrants, of whom 17,327 have completed the course recommended for placing in employment. *K. M. A. Perry.*

THE SCOPE OF THE JOURNAL

During its short life of ten years, the main purpose of the British Journal of Industrial Medicine has been to publish original scientific papers. There is to be no change in policy, although we have sought recently to enlarge the journal's scope and so make it both useful and interesting not only to industrial medical officers, safety engineers, and research workers but also to those whose work merges imperceptibly into the province of industrial medicine. We have in mind many, such as managers and personnel officers, who are inevitably concerned with human relations in industry and therefore with health in the widest sense. The social and psychological problems arising from conflicts between working groups and people inside groups probably demand as much attention as those between man and his physical environment at work ; moreover the successful control of a physical hazard often demands social and psychological action in getting a community to apply preventive measures.

In the past 18 months we believe that in some measure we have encouraged a wider interest since we have had requests for reprints and extra copies of the journal from many people outside our usual orbit.

In this number we introduce a new section, Miscellany, to encourage a still wider range of contributors and thus to increase the interest and, we hope, the usefulness of our journal. As the name implies, it is intended to contain a variety of contributions which are shorter than those in the main section for original papers. We shall include in it scientific observations which are still in the preliminary stage, and notes of special interest such as the short account of the treatment of tenosynovitis at work (p. 200). Where the theme of a book inspires the reviewer to expand the usual book review and add to it from his own experience here is the place for such an essay, as the one on page 209 by Sir Alexander Hood based on *The Report of the Health of the Army*, and Dr. Andrew Meiklejohn's thoughts on reading a study of the sewerman at work. This group of underground workers has not before been considered in relation to their environment and occupational and social health except in connexion with Weil's disease, and Dr. Meiklejohn is therefore bringing to our attention something new.

Here also we would publish accounts of any special experiments in providing health services for industry. In this number we include a description of the work of an occupational hygiene team in a group of small factories, because in many respects it is a new concept of service in Great Britain and seems to have met a considerable need on the Slough Trading Estate.

We also hope to publish other contributions such as descriptions of new treatments and new apparatus concerned with industrial health and safety. And lastly, but not of least value, this is the opportunity for a public riposte from those who perhaps disagree with a conclusion or point of view expressed in the journal and have the facts wherewith to buttress their opinions.

We take this opportunity of emphasizing that original scientific papers dealing with all aspects of occupational medicine are our first concern and will continue to form the most important section of this journal. But we now offer a place for the shorter paper which has something of definite value but cannot strictly be included in the main section.

Brit. J. industr. Med., 1953, **10**, 142.

THE PRE-IMPINGER

A SELECTIVE AEROSOL SAMPLER

BY

K. R. MAY and H. A. DRUETT

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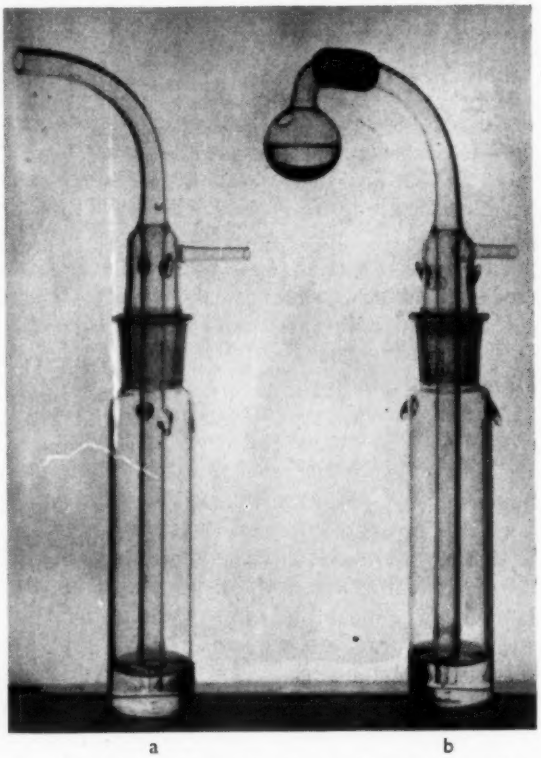
When airborne particles are inhaled it is known that most of those of effective diameter greater than about 5 μ are filtered out by the upper respiratory tract. Current knowledge of this subject as reviewed by Davies (1949, 1952) indicates that the size of particle which has a 50% chance of passing through the upper respiratory tract lies somewhere in the range 3½ μ to 5 μ. Toxic effects from the inhalation of airborne particles are closely related to the size and site of deposition of the particles. With coal dust, for example, it is now generally accepted that danger lies only in the particles which are small enough to reach the alveoli. Other dusts acting as systemic poisons may be absorbed through the nasal mucosa. With airborne anthrax particles a great increase in infectivity has been demonstrated as the particles diminish below 4 μ (Druett, Henderson, Packman, and Peacock, 1953).

An ideal sampling instrument for airborne particles would allow a complete size-distribution of the particles to be obtained quickly from a perfect sample of the cloud. This is usually impossible but, as Davies (1952) points out, for estimating the respiratory hazard much useful information will be given by an instrument which merely discriminates between particles which can and cannot reach the lung. An approximation to this is given by the standard "Porton" impinger shown in Fig. 1a. This device is a development of the Greenburg and Smith impinger (1922) and its impinging jet is an 11-litre per minute critical orifice which gives very high collection efficiency down to the size of single bacterial cells (0·5 to 1 μ). The curving intake tube traps wet particles down to roughly 12 μ, the smaller particle fraction being collected in the liquid of the flask. This cut-off is very much higher than that of the human nose, and when vegetative organisms which can be killed by desiccation are sampled, those which adhere to the dry walls of the intake tube are likely to be lost. It is also possible that the occasional large dry particle will succeed in bouncing through the curved tube, thus giving a highly variable sample in the flask, especially where bacterial clusters are concerned.

To overcome these faults of the impinger our primary requirements were to develop a device which would first divide the bacterial aerosol sample into



a b

FIG. 1 (a).—Standard "Porton" impinger, (b) pre-impinger on front of impinger.

two fractions, the cut-off being at a specified figure in the $3\frac{1}{2}$ μ to 5 μ range, and second, collect both fractions directly into a suitable liquid with no chance of the penetration of large particles. The " pre-impinger ", shown in place in Fig. 1b, performs this function efficiently. It is a spherical glass bulb, half filled with collecting liquid with an air intake hole in the front.

To obtain a good estimate of the total airborne concentration, it is of course necessary to keep all sampling losses as low as possible. In an instrument which sucks in airborne material through a tube and deposits the particles by impingement, physical sampling errors are of four distinct types and the elimination of each is a separate problem.

The types are (1) intake errors, when particles have sufficient inertia to prevent them following sudden directional changes in the sampled streamlines of flow near the orifice. The errors are functions of the velocities of the ambient and intake tube air streams, the dimensions, nature, and orientation of the orifice, and the particle size ; (2) loss from particles striking and being retained by the internal walls of the apparatus, including the walls of the intake tube before reaching the site(s) of impingement ; (3) loss from inefficient adherence or retention of particles on the site of impingement ; (4) loss from the impingement jet having insufficient velocity to throw out the finer particles which are then carried through the instrument with the airstream.

The pre-impinger has been designed to keep these various errors to a minimum, after fulfilling the two primary requirements already given. There is no chance of entirely eliminating type (1) and (2) errors in the case of the pre-impinger in horizontal winds because the entering airstream must be deflected downwards to strike the necessarily horizontal liquid surface, but, as shown by experiment, these losses are never excessive under normal sampling conditions. Type (3) losses appear to be nil with airborne particles consisting, for example, of dye or micro-organisms from a spray of an aqueous solution or suspension. With other particles however, such as dust, this would not necessarily be so unless the particles were immediately wetted on striking the surface of the collecting liquid and removed from it at once by solution or turbulent mixing. Thus coal dust may be inefficiently collected with water in the bulb as it tends to form a dry film on the surface. Kerosene is good for sampling coal dust and Fig. 2 shows the two fractions of a coal-dust cloud recovered from this liquid. The photographs illustrate the completeness of the cut-off.

The cut-off may be set at any desired particle size in the range of nasal penetration by altering the size of the intake orifice, which in turn alters the jet velocity and so the type (4) loss. For our purpose the orifice is made so that 50% of 4 μ particles (density 1·3) penetrate to the impinger operating at 11 litres per minute. This is shown to be so both for spherical particles of dye made by the evaporation of sprayed homogeneous mists of the dye solution and for spherical clusters of micro-organisms similarly obtained from aqueous suspension.

Features of the pre-impinger are that it has an extremely high impingement efficiency in relation to its jet velocity and that the liquid level is not in any way critical. These are due to an interesting and fortunate double impingement process on the

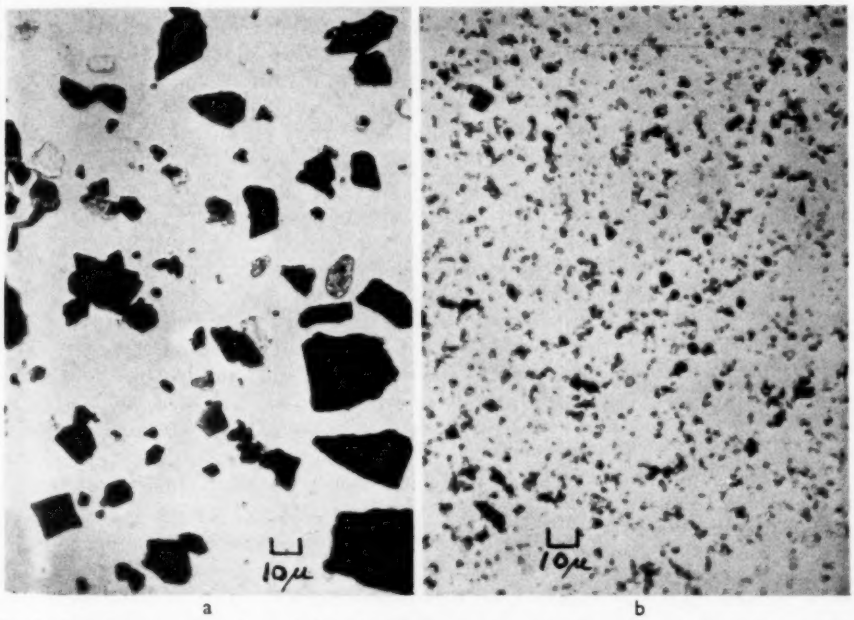


FIG. 2.—The size separation of a coal dust cloud given by the pre-impinger plus impinger unit, both filled with kerosene (× 350) ; (a) pre-impinger sample ; (b) backing impinger sample.

liquid surface, first by the jet and secondly by a tight vortex at the meniscus The liquid surface is only slightly dented by the jet in our standard bulb.

Design Considerations

Various shapes for the pre-impinger were tested and the final forms chosen are shown in Fig. 3. In shape A,

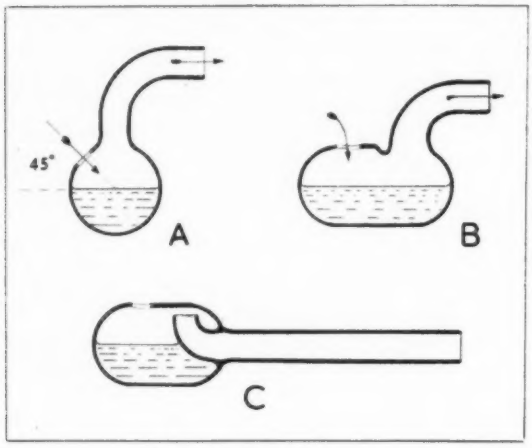


FIG. 3.—Types of pre-impinger.

the most generally useful form, the glass bulb is 30 mm. O.D. × 28–29 mm. I.D. and the smoothly curving neck is 10 mm. O.D. × 8 mm. I.D. The intake hole is ground out in the position shown so that the axis of the air jet strikes the centre of the liquid surface at 45°. The horizontal part of the curving neck is well above the bulb, so that when the unit is handled (with a bung in the intake hole), there is little danger of any of the liquid splashing over into the backing impinger.

To give 50% retention of 4 μ bacterial particles the intake hole is ground out to 6·5 mm. ± 0·25 mm., as checked with a gauge, and lightly chamfered to remove sharp edges. The decision to set the 50% retention at this figure was taken after careful consideration of current knowledge on nasal penetration and lung retention. As we are primarily interested in sampling bacterial aerosols, weight was given to the work of Druett and others (1953) with anthrax particles and Harper and Morton (1953) with radioactively labelled particles. In these experiments a striking agreement was found for the guinea-pig between nasal penetration and infectivity, the particle size where rapid change took place being about 3½ μ.

Shape B in Fig. 3 has a low intake efficiency for windborne clouds but is efficient in static clouds and has rather less danger of spilling when the intake hole is open. The impingement efficiency of shape B is a little lower than that of A (Table 1).

Shape C is an adaptation of B so that samples may be taken inside a vertical duct with a downflowing air-stream by inserting the whole pre-impinger through a hole in the duct wall.

A principal feature of the design was that an intake tube was avoided. Fabrication of the bulb is thereby simplified and intake tube loss of type (2) is eliminated. These considerations were thought to outweigh the fact that the bulk of the bulb round the orifice might cause higher type (1) errors in a windborne cloud than would be given by a more isolated orifice at the end of a tube. On the other hand, in yawing or turbulent wind, type (2) loss in an intake tube would probably make it less efficient overall than the plain hole in the bulb wall.

Test Procedure and Results

Production of Test Aerosols for Measurement of Impingement Efficiency.—Dry spherical particles, homogeneous and rigidly controlled in size, were generated in a vertical wind tunnel (Druett and May, 1952) by a modified form of the Walton and Prewett (1949) spinning disk spray. Solutions of the purified dye "chlorazol sky blue F.F." (I.C.I. Ltd.) were made up in water to strengths of 1% or 0·2% according to the particle size being investigated and 0·1% of "tergitol" was added to the solution to improve the wetting of the disk and therefore the uniformity of the clouds. The solutions were sprayed from a ground-glass surfaced rotor into a dry atmosphere, solid spherical particles of dye (density 1·33) being left after the evaporation of the water. Very uniform clouds of any desired particle size, which are ideally suited for testing the performance of any particle sampling or filtration system, are produced in this way. Pre-impingers backed by standard 11 litre-per-minute impingers were exposed to the test clouds for long enough to give easily measured amounts of dye in each of the two fractions of the sampler. Estimations of dye concentration were made on a Spekker colorimeter. The method is quick and accurate.

To check that the dye cloud results could be applied to the sampling of airborne micro-organisms, aqueous suspension of spores of *B. subtilis* were sprayed in the same way to give dry spherical clusters of spores of the desired diameter. Impinging on water, these immediately disperse to become single organisms. The number in each sample was estimated by the method of Miles and Misra (1938). This procedure is slow and only sufficient bacterial samples were taken to make a valid check on the dye method.

Radioactively labelled spores of *B. subtilis* were sprayed in another experiment and estimated by the Geiger count, using the procedure described by Harper and Morton (1952).

The density of the spore clusters was not measured but we are informed (Powell, 1953) that it would be in the region of 1·3 to 1·4.

Particle Size Measurement.—Samples were withdrawn from the wind-tunnel through the appropriate stage of a Cassella cascade impactor and measured with a microscope eyepiece graticule. As the dye particles are black, spherical, and very nearly uniform in size, the measurement can be made with ease and accuracy. The usual procedure was to measure about 100 particles, arranging them in $\frac{1}{2}$ micron wide size groups. The mean volume diameter $(\Sigma Nd^3/\Sigma N)^{1/3}$ was then found but in practice the overall size range in a given sample was so small that it made little difference whatever statistical mean was taken. Inspection of the sample and measurement of one or two particles of the predominant size (at 5μ for example, 80% of the particles were in the range 4·75 to 5·25 μ) gave a quick and accurate check when setting the cloud to the desired size.

The clouds of spore particles were measured in the same way. Sizing is not so accurate for this type of particle because (*a*) the initial droplets from the spray are not usually quite so uniform for suspensions as for solutions, (*b*) there is a statistical variation in the number of spores per droplet which tends to spread out the size range of the dried particles, particularly when the particles are small and contain only a few spores, and (*c*) the dried spore clusters are often lumpy and unspherical. The lower uniformity was a further reason for carrying out the detailed calibration with dye particles, using the spores only as a check.

Estimation of Particle Size Cut-off.—This was carried out in detail for the shape A pre-impinger with 6·5 mm. orifice at 11 litres per minute over the range between just measurable particle retention (at 1·9 μ) to just measurable penetration (at 8 μ). The curve obtained is shown in Fig. 4. In this work six pre-impingers were selected at random from a large production batch and for each particle size three samples were taken with each pre-impinger and impinger unit. Thus each point plotted is the mean of 18 determinations, except for the extreme points where the very long exposure necessary to obtain measurable samples allowed time for only six determinations. The results showed no significant difference between the six pre-impingers. Standard deviations of the full results for the various particle sizes lay between 0·8 and 4%. The two points estimated by the Miles and Misra method from samples from clouds of *B. subtilis* clusters are also shown in Fig. 4. These are the means of one exposure from each of the six pre-impingers and are seen to lie close to the dye curve, confirming the applicability of the latter to bacterial sampling.

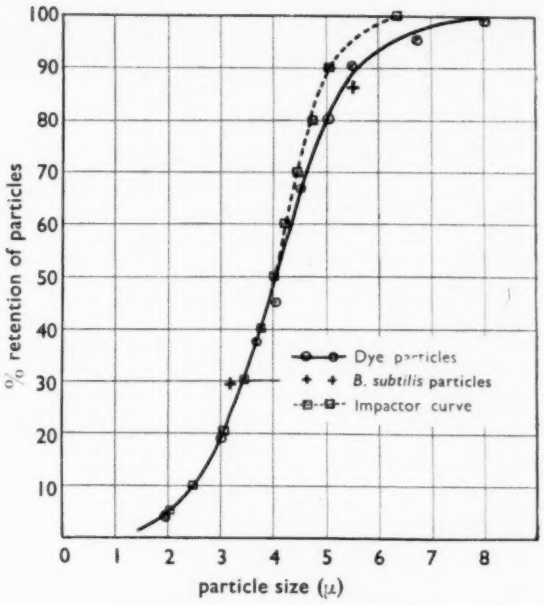


FIG. 4.—Impingement efficiency of pre-impinger with 6·5 mm. orifice at 11 litres per minute.

Further confirmation of this was obtained with the radioactively labelled spore clouds sampled with pre-impingers of shapes A and B with 5 mm. orifices at 11 litres per minute when the following figures were obtained (Table 1).

TABLE 1

	Shape A		Shape B	
	Dye Cloud	Labelled Spore Cloud	Dye Cloud	Labelled Spore Cloud
Cloud particle size (μ)	3·5	3·7	3·5	3·7
Retention (%)	75·5 (by Spekker)	72 (by Geiger count)	49·8 (by Spekker)	49·1 (by Geiger count)

These results also show that shape A pre-impinger is more efficient in retention than shape B, both having the same size of intake hole and flow rate.

The " impactor curve " in Fig. 4 was obtained from the figures given by May (1945) for the performance of impacting jets. The curve is that of a jet-to-dry-plate system with a 50% retention at 4 μ and it is strikingly similar in shape to the pre-impinger curve. The experimental curves of Ranz and Wong (1952) are also similar in shape, but Davies and Alyward's theoretical curves (1951) do not agree so well. The agreement between May's and Ranz and Wong's curves and the pre-impinger curves is in shape only, however, for their empirically

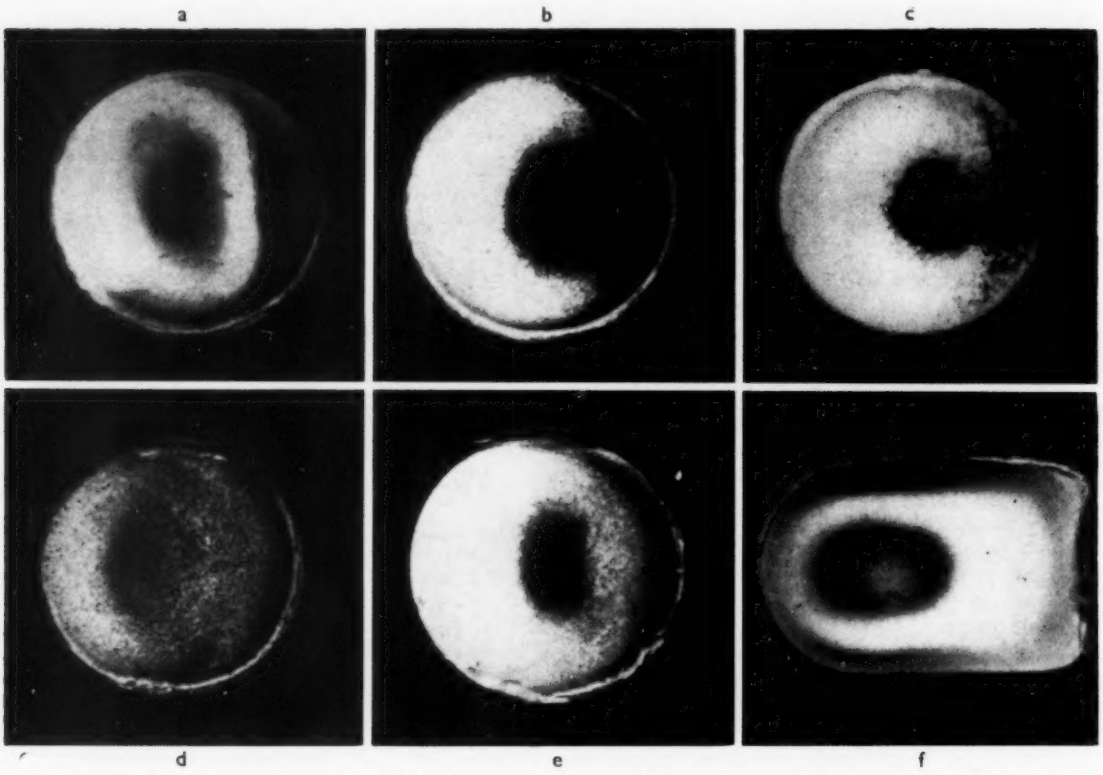


FIG. 5.—Patterns showing sites of impingement on the liquid surface in the bulb : (a), (b), (c), 6·5 mm. intake hole, 11 litres per minute; (a) 4 μ particles ; (b) 7·5 μ, (c) 10 μ, (d) 9 mm. hole, 11 litres per minute, 6 μ particles ; (e) 4·3 mm. hole, 4·6 litres per minute, 4 μ particles ; (f) Shape B pre-impinger with 6·5 mm. hole, 11 litres per minute and 4 μ particles.

evaluated formulae give, for the pre-impinger dimensions, a 50% retention in the $7\frac{1}{2}$ to 9 μ region instead of 4 μ.

Mode of Impingement.—The reason for the exceptionally high particle retention efficiency was not revealed until a study was made of the pattern of impingement on the liquid surface. To do this a bulb was cut in two round the normal waterline and waxed together again. The bulb was then half filled with a thin plaster of paris suspension. Just before the plaster reached setting point a sample of suitable density was taken from the blue dye cloud to give a blue stain on the white plaster at the sites of impingement. If the airflow was continued until the plaster had set, the dent in the liquid surface was " frozen " for study and measurement.

Photographs taken of the plaster surfaces with the upper half of the pre-impinger removed are shown in Fig. 5. In each case the inlet hole was on the left with the exhaust tube on the right (as in Fig. 6c). They show that impingement takes place in two stages, first from the jet as it strikes the liquid surface, giving the dark central spots, and second from a tight vortex at the back of the bulb which gives the crescent-shaped marking. The latter is much more efficient in impingement than the jet as shown by Fig. 5a. Here, 4 μ particles (the size for 50% retention) have been sampled in the standard bulb (11 l./min., 6·5 mm. hole) and it is clear that much the greater mass is deposited by the vortex. The efficiency of the jet alone is as predicted by Ranz and Wong's figures except that there is a slight enhancement due to the denting of the liquid surface. As the particle size increases, the proportion impinged by the jet also increases. This is shown by Fig. 5b where 7·5 μ particles are sampled under the same conditions as Fig. 5a and are about equally distributed between jet and vortex, and in Fig. 5c where at 10 μ the jet impinges much more than the vortex.

The relative importance of the vortex varies with the size of the hole. Fig. 5d shows the pattern in a bulb with a 9 mm. hole which gives a 50% retention

size of 6 μ at 11 litres per minute. Here the vortex is predominant and envelops most of the liquid surface. With a small hole, however, the vortex has less effect as shown by Fig. 5e, taken from a bulb with 4·3 mm. hole at 4·6 litres per minute with 4 μ particles (50% retention).

Fig. 5f shows the pattern in the shape B bulb sampling under identical conditions to 5a. Here, the vertical jet makes a greater dent in the liquid than the 45° jet and is thereby more efficient, but the vortex in this shape is of relatively less importance and the overall efficiency is found to be slightly less.

This vortex formation is extremely useful in that it enables the 50% cut-off of the bulb to be achieved with a negligible drop in pressure at a low particle size which, without the vortex, would require a high-velocity, liquid-disrupting jet. It also ensures that there is no chance of over-size particles getting past the pre-impinger. The configuration of the vortex impingement patterns in Fig. 5 would suggest that there would be heavy impingement on the wall of the bulb also. In fact this is not so and such wall deposition as there is takes place just above the meniscus. It is therefore important to ensure that the glass is clean and well wetted by the liquid so that the meniscus reaches as high as possible.

Effect of Varying Intake Hole Diameter and Sampling Rate.—The performance of geometrically similar jet-to-dry-plate particle impactors may be given by an equation of the form

$$I_n = \rho V d_n^2 / \eta l \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where I is the dimensionless impaction parameter which varies with n, the impaction efficiency, i.e., the chance of a particle of diameter d and density ρ striking the plate. V is the jet velocity, η the gas viscosity, and l a characteristic length of the system, usually the jet width. For a circular jet nozzle Ranz and Wong (1952) found $I = 2{\cdot}7$ at $n = 0{\cdot}5$.

It was thought that an equation of similar form might hold for the pre-impinger enabling the dimensions of bulbs to be calculated when used at other flow rates or as selective filters with other apparatus. To test this, bulbs were made at the standard diameter only, with intake holes over a range from 2·65 mm. to 9 mm. diameter and tested at sampling rates between 1·20 litres per minute and 39 litres per minute. From each test the dye particle diameter giving 50% retention ($d_{0{\cdot}5}$) was obtained.

It was found that there was an inverse relationship between I and l (the intake hole diameter) and that for a given l, I remained nearly constant for any jet velocity which could be used for that size of hole. These effects are explained by the relative magnitude of the vortex and jet impingements, for, as already shown, a large hole gives a large vortex and vice versa (Figs. 5d and 5e). As l diminishes below 3·5 mm. I becomes equal to, then exceeds, Ranz and Wong's value for a plain jet, showing that the vortex effect disappears when we have a long, thin, diffusing jet of air. The vortex could no doubt be reintroduced by scaling down the bulb in proportion to the hole provided that the jet velocity is not high enough to disrupt the liquid surface. $I_{0{\cdot}5}$ ought then to be nearly constant at about 1·0 for all values of l.

The experimentally determined relationship between I and l showed variations beyond the range of experimental error. This is perhaps not surprising in view of the lack of geometrical similarity in the experiments and the variable importance of the vortex. Nevertheless a plot of

$$I_{0{\cdot}5} = (\cdot 307/l) + 0{\cdot}53 \quad .. \quad .. \quad .. \quad (2)$$

passes fairly well through the experimental points and substitution in equation (1) will give $d_{0{\cdot}5}$ to better than ± 10%. At $l = 6{\cdot}5$ mm. and above, the error in $d_{0{\cdot}5}$ is very small.

Values of d for other values of n may be found from Fig. 4 by proportion, the efficiency curves being quantitatively similar in all cases.

The validity of equation (1) in respect of ρ and η was not tested. When the pre-impinger is adjusted to give a similar cut-off to the human nose the similarity should apply regardless of the density and shape of the particles, for a process of inertial impingement on to wet surfaces occurs in both cases.

Available Range of Cut-off.—The lower end of the range with the standard 3 cm. bulb is limited to the point where the jet velocity becomes so high that the liquid in the bulb is disrupted and entrained in the air stream into the backing impinger. For any combination of l and V this limit is reached when $d_{0{\cdot}5} \approx 2{\cdot}25$ μ. The upper limit of cut-off size is set by the increasing proportion of particles trapped in the connecting tube and on the back of the bulb as $d_{0{\cdot}5}$ increases. Without an extravagant increase in bulb and tube size it is on this account impracticable to set $d_{0{\cdot}5} > 8$ μ.

Streamlines of Flow into the Orifice.—Fig. 6 shows a selection from photographs of pre-impingers in a streamlined-flow wind tunnel sampling in winds of various speeds. The lines of flow into the orifice are made visible by filaments of smoke introduced from fine jets upstream of the orifice. The photographs were taken to study the effect of various wind speeds on the entry conditions and it was also possible to observe, but not photograph, the initiation of vortex circulation within the bulb at low suction rates. In Fig. 6a, where the wind speed

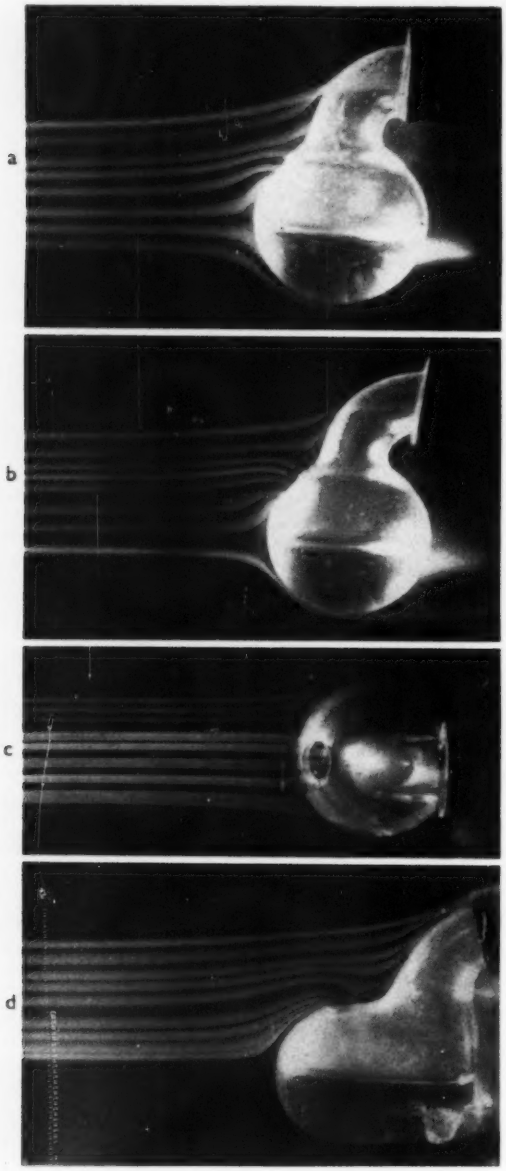


FIG. 6.—Streamlines of flow past pre-impingers: (a) 12 m.p.h. wind; 11 litres per minute suction; (b) 4 m.p.h. 11 litres per minute; (c) 4 m.p.h. 11 litres per minute; (d) 8 m.p.h. 11 litres per minute.

(12 m.p.h.) is about the same as that in the orifice, it will be seen that the streamlines entering the orifice do not bunch together as they do in the lower wind speed of Fig. 6b. This sudden bunching in front of the orifice throws out the larger particles from their "carrier" streamlines of flow into the orifice and the particles are lost on the exterior of the bulb. Fig. 6c shows the horizontal pattern of flow into the orifice. Fig. 6d shows a shape B pre-impinger and demonstrates its unsuitability for horizontal air streams.

Estimation of Sampling Errors

Intake (Type 1) Errors.—For this purpose an extensive series of samples was taken in a horizontal wind tunnel in the mouth of which a spinning disk sprayer dispersed uniform droplets of dibutyl phthalate dyed with the red dye "B.1" for colorimetric estimation. The tunnel had a 6 ft. long expanded turbulent mixing section followed by a contraction to smooth out the flow into the "open-jet" type of working section. Flow was maintained through the tunnel by a suction fan of controllable speed. The open jet was 4 in. by 8 in., which allowed room for four samples to be taken simultaneously. The procedure was to compare the recovery from the inside of two pre-impinger plus impinger units mounted alternately with two standard impinger units equipped with knife-edged isokinetic orifices designed to give the best possible estimate of the cloud concentration. All the sampling orifices face upwind and were placed as close together as possible, consistent with the avoiding of mutual interference. Experiments were made at droplet sizes of 10, 15, 20, 25, and 30 μ at 2, 4, 6, 8, 12, and 16 m.p.h. wind speed at each droplet size and all runs were triplicated in the first instance. A survey of the curves so obtained then indicated doubtful or key points which were finally established by tenfold repetition of the point in question. The coefficient of variation of the latter determinations averaged 4·5%.

To obtain the intake efficiency in a static cloud, (0 m.p.h.) the spinning-disk spray was set up over a hole at the top of a 33 in. square and 4 ft. high chamber. The sprayed droplets settled down through the hole and were mixed at the top of the chamber by a low-speed multiple air-jet. Sampling took place at about 12 in. from the floor of the chamber, the absolute sample being taken by a knife-edged and externally streamlined nozzle of 1·56 cm. diameter whirling horizontally at 30 r.p.m. at the end of a 30 cm. radius arm. This nozzle is isokinetic because at 11 litres per minute suction air enters it at the same velocity as the rotational velocity. Six equally spaced pre-impingers were set up just outside the path of the whirling nozzle and at the same level. To obtain the intake efficiency, the mean of the six samples was compared to the nozzle sample. Good agreement was obtained in replicated experiments (coefficient of variation,

4·3%). At the sampling level there was some turbulence of low velocity relative to the intake velocities of the sampling orifices due to the mixing jets, but the mean horizontal velocity was zero. A mean downward movement of the cloud, in addition to the sedimentation velocity of the droplets, of 0·19 cm. per second was due to the withdrawal of 77 litres per minute through the samplers. Experiments were done at 20 μ and 30 μ only, the results being so close together as to enable the efficiencies at other sizes to be estimated without the possibility of appreciable error.

The results are plotted in Fig. 7 in which the "% intake efficiency" is the ratio between the pre-impinger and isokinetic orifice samples, the latter being assumed absolute.

The accepted picture of the sampling errors of an orifice facing upwind is that when the ambient wind speed is lower than that in the orifice, particles overshoot the streamlines converging into the orifice (cf. Fig. 6b) resulting in a deficient sample, and conversely when the wind speed exceeds the orifice speed, particles undershoot the diverging streamlines giving an excessive sample. These effects should increase with the inertia of the particles. At zero wind speed when the particles settle freely into the sampling zone, the intake efficiency should be high.

These effects are well shown by the Fig. 7 curves from which we see at zero wind speed the intake efficiency is high for all particles (an additional determination at 50 μ gave 85·5% intake). At 12 m.p.h. the wind speed is the same as the orifice speed, and in this region intake efficiencies are again high for all particles, in spite of the bulk of the bulb around the orifice and the 45° angle of the orifice. The drop in efficiency due to the particles overshooting the streamlines is greatest at 6 m.p.h. for all particles >10 μ and the drop increases with the particle size. At 30 μ the intake is only about 58% at 6 m.p.h. and for still larger particles, say 50 μ, the intake is probably below 50% at this speed. At wind speeds higher than the orifice speed the intake tends to exceed 100% for all particles >10 μ. Particles smaller than 10 μ are sucked in with virtually 100% efficiency under all conditions within the limits of the experiment.

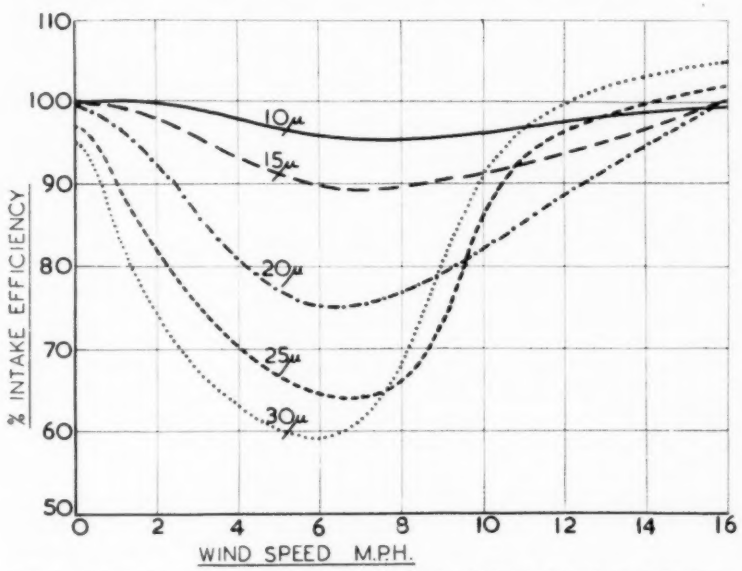


FIG. 7.—Effect of wind speed and particle size on intake efficiency of standard pre-impinger

Lack of time and certain experimental difficulties have so far delayed the extension of the curves beyond 30 μ and 15 m.p.h. and for negative wind velocities, but the range investigated should cover most practical cases.

The saddle shape of the efficiency curves agrees well with those of Hirst (1952) who performed experiments on the intake efficiency of an impactor device sampling lycopodium spores.

The effect of yaw on the intake efficiency has not been investigated but this should be small because there is no intake tube.

Internal Wall and Tube (Type 2) Losses.—Deposition on the back of the bulb can take place from two causes; first from the vortex, or second from large windborne particles which have sufficient horizontal momentum when sampled to carry them out of the air jet before the liquid surface is reached.

Deposition from the first is close to the liquid surface unless there is a large intake hole, when the large vortex (cf. Fig. 5d) tends to spread particles over the whole of the back of the bulb. Deposition from the second is a function of d^2v and in practice begins at 30 μ and 8 m.p.h., 20 μ and 16 m.p.h., and so on.

The back wall deposit is only likely to be lost in the case of viable particles sensitive to drying as it is very easy to wash off by shaking the bulb with the intake closed. This should be done as a routine before withdrawing the liquid. The estimation of the back wall deposit has not been

made but the conditions in which it is likely to give appreciable loss in our work are rarely encountered.

The small particles surviving the initial impingement in the bulb are subject to deposition in the curving tube connecting the bulb to the backing impinger. This, again, is only a loss with viable particles sensitive to drying as the tubes can be washed through. The magnitude of the particle deposition in these tubes was estimated during the course of the determination of the detailed cut-off curve of the standard bulb (Fig. 4). It was found that below the 50% retention size no measurable dye could be found in the tubes, but as the particle size increased an increasing proportion of the penetrating cloud was retained in the tube. Thus at 5·03 μ, 5·5% of the total of particles entering the pre-impinger were recovered from the tubes, this being 28% of the particles penetrating the pre-impinger. At 6·75 μ the recovery was 2·25% of the total, being 50% of the penetrating cloud. In drawing the cut-off curve of Fig. 4 the tube recovery was added to the impinger sample. If the tube recovery is added to the pre-impinger sample, or neglected, the effect is to raise the upper half of the curve slightly so as to lie about midway between the existing curve and the impactor curve.

Because the tube loss forms only a small proportion of the total sample and the size range at which loss takes place is only 4 to 8 μ, there is no doubt that in the typical cloud of particles of widely dispersed sizes the tube loss in the standard bulb can be ignored. A narrower tube would, of course, give higher losses.

Discussion

The results obtained show that at wind speeds from zero to at least 16 m.p.h. the pre-impinger and impinger unit is capable of giving a good estimate of total cloud concentration of all airborne particles below about 30 μ plus a quantitative measure of the proportion of the aerosol capable of reaching the lung.

The sigmoidal shape of the cut-off curve in Fig. 4 has been found to apply to bubbler sampling devices as well as to impingers and impactors and it seems very likely that such a shape would apply to the nose. Although the nose cut-off curve may be less steep than that in Fig. 4, the cloud reaching the impinger should resemble in size-distribution that which would reach the lung.

It might be thought that the size fractionation of the aerosol could be extended further by employing several liquid impingement stages in series in the manner of the " cascade " impactor. It is, however, scarcely practicable to do this for large particles because the air stream must be made to turn 180° (or nearly so) between each liquid stage and the large particles cannot be made to do this without being thrown out on the bend. The present work shows that the available range of cut-off sizes is limited to 2·5 μ to 8 μ and a complete re-design would be necessary to extend this. In its present form the unit described in this paper is thought to be the simplest way of obtaining the really essential information when sampling toxic aerosols. The high intake efficiency found for still air sampling suggests that for a continuous windborne cloud a more accurate sample of large particles might in some circumstances be obtained by bringing the cloud to a standstill before sampling, e.g. at the stagnation point of a baffle, rather than attempting the usually impossible task of obtaining continuously isokinetic sampling. For example, at 30 μ in a 6 m.p.h. wind the intake of the bulb is 58% (Fig. 7). This may be increased to about 80% with the bulb sampling through the centre of a 4 in. diameter baffle normal to the wind direction. This consideration would apply to sampling devices in general.

Particle size-separation as given by the pre-impinger can, of course, also be achieved by (i) a jet-to-dry-plate impaction device, or (ii) an elutriator or settling chamber. We have given reasons why collection into liquid is to be preferred for viable organisms but in the case of say, dust samples, the pre-impinger has an advantage over (i) above in that no overloading or clogging up at the site of impaction can take place and there are no type (2) losses, and over (ii) in compactness and ease of recovery of the sample. The pre-impinger is also inexpensive and easy to make. A disadvantage of the standard shape is that the liquid can be fairly easily spilt when the orifice is open so that the device is not very suitable for sampling from the hand. This fault could not be overcome without seriously affecting the windborne cloud intake efficiency, though in still air the alternative shape B gives high intake efficiency with little chance of spilling. The assembly shown in Fig. 1b could, of course, be made more compact by sacrificing the curving neck of the impinger and leading an internal-sealed tube straight down from a modified pre-impinger bulb into the impinger flask.

Summary

A simple device is described which, when fitted to the front of an impinger, divides the total aerosol sample into two particle-size fractions by means of

size-selective impingement into liquid. The cut-off between the two fractions is set at 4 μ to simulate nasal penetration.

The curve of efficiency of impingement of particles into the liquid against particle size shows that the pre-impinger has a very high efficiency in relation to its jet velocity. This is due to a double impingement process on the liquid surface.

The particle intake efficiency at various wind speeds is given in detail and is shown to be good for particles smaller than 30 μ. Empirical equations are given to show the relation between cut-off size, intake hole diameter, and jet velocity so that the cut-off may be set to any other desired figure in the range $2\frac{1}{2}$ μ to 8 μ. Internal losses were evaluated and shown to be small. Streamlines of flow into and around the device were investigated by means of smoke filaments in a wind tunnel.

It is concluded that the particle retention of the pre-impinger is similar to that of the nasal passages, while the material in the backing impinger is similar to that reaching the lungs. The pre-impinger appears to have some important advantages over other devices for selective sampling such as dry impaction systems, elutriators, and settling chambers.

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STUDIES ON THE NATURE OF SILICOSIS

THE EFFECT OF SILICIC ACID ON CONNECTIVE TISSUE

BY

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From the University of Reading

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Contemporary studies indicate that connective tissue is a coarse network of collagen on which is superimposed a finer network of fibres visible only in the electron microscope (Wassermann, 1951). An amorphous ground substance, which is responsible for the high resistance of the tissue to the passage of fluids, appears to consist of collagen fibrils which are just visible in the electron microscope and are embedded in mucopolysaccharides of high molecular weight.

Much of the evidence for this conception of the structure of connective tissue has been derived from light- and electron-microscopic studies. The sieve-like structure of the collagen network has also been demonstrated by comparing the rate at which saline will flow through animal membranes before and after treatment with hyaluronidase (Day, 1952). Hyaluronidase, by removing the polysaccharides, largely increases the tissue permeability but the permeability is again reduced if the tissue is treated with mucopolysaccharides, such as chondroitin sulphate, or with certain other macromolecules.

The function of the polysaccharides in connective tissue is not understood with certainty, but it is thought that they behave as a filling material packed into the collagen network and that they orientate and perhaps cement together the collagen fibrils to form fibres (Partridge, 1948). Some similarity is suggested between the function of chondroitin sulphate in the production of normal tissue fibres and that of silicic acid in the production of pathological fibrous tissue. Silicic acid, in its polymerized form, may orientate collagen fibrils already present in the tissue with the production of the long, thick, collagen fibres characteristic of silicotic tissue. Consequently, an examination has been made of the effects of dilute silicic acid sols on hyaluronidase-treated membranes to determine whether their action is similar to that reported by Day (1950) for chondroitin sulphate.

Methods

Preparation of Silicic Acid Sols.—The sols were prepared by fusing pure powdered silica with sodium carbonate, the quantity of the latter being calculated to give a 0·85% saline solution when the melt was subsequently dissolved in water and neutralized with hydrochloric acid. When more dilute solutions were prepared these stock solutions were diluted with 0·85% saline. Solutions were brought to *p*H 5–5·5 or *p*H 7–7·5. No difference attributable to *p*H was found between the action of the silicic acid in the two ranges. Viscosities of solutions were measured but differences were too small to affect the rate of flow.

Measurements of Permeability.—The method described by Day was closely followed. A sheet of subcutaneous tissue from the flank of a rat is attached to the lower end of a vertical tube of about 5 mm. diameter. The permeability is measured by running saline or other solution into the tube then recording the time required for the meniscus to travel between two marks on the tube, the lower being 4 cm. above the membrane. Hyaluronidase is then added to the saline and the permeability is again measured.

If the original rate of flow is small (e.g. 0·006 ml. per minute) and a large increase in permeability is recorded (e.g. to 0·03 ml. per minute) the preparation is considered suitable. Saline will then flow through the membrane either at a constant or at a steadily decreasing rate.

Experimental Results

A summary of the experimental results is given in the table.

Sol Concentration.—Fresh sols containing 0·04 g. SiO_2 per 100 ml. or more were effective in reducing the permeabilities of membranes. Fresh sols containing 0·008 g. SiO_2 per 100 ml. or less had no

TABLE
EFFECT OF SILICIC ACID ON MEMBRANE PERMEABILITY

Silicic Acid Concentration (g./100 ml.)	Positive (No. of Experiments)	No Effect (No. of Experiments)
Fresh sol		
0·2	11	4
0·08	7	0
0·04	2	0
0·008	2	8
0·004	0	3
0·002	1	6
Sol aged for 2 hr.		
0·2	10	0
0·08	3	0
Sol aged for 24 hr.		
0·08	7	0
0·04	2	0
0·008	10	0
0·002	4	0

detectable effect. The method is not suitable for the detection of quantitative differences between the effects of different concentrations. Fig. 1 shows the effects of a series of aged sols applied to a single membrane. It is impossible to state positively that the more concentrated sols are more effective in reducing the permeability of the membrane.

Polymer Size.—The effect of polymer size on the ability of sols to reduce the permeability of the membrane was studied by using sols which had been allowed to polymerize for different lengths of time. Polymerization is most rapid at about *p*H 5·5–6 but is very slow in strongly acid or alkaline solutions. The *p*H of alkaline sols was brought to this value. In some cases the sols were used immediately but in others after a measured time interval.

Aged sols were found invariably effective even in concentrations as low as 0·002 g. SiO_2 per 100 ml. Fresh sols were ineffective at this concentration but, as the concentration was increased, showed increasing effectiveness. In a number of cases aged and fresh sols of the same concentration were applied consecutively to the same membrane. The fresh sol was invariably much less effective in reducing permeability than the aged sol (Fig. 2). No difference was detected between sols aged for two hours and others aged for 24 hours.

Discussion

Silicotic lesions are produced by particles of free silica acting on normal lung tissue. It is still uncertain whether silicates can produce a similar tissue reaction ; there is increasing evidence that certain silicates are effective although the reaction they induce is much less intense. Certainly some siliceous dusts which are inhaled in heavy concentrations do not produce silicotic lesions ; cement is one example.

It is no longer supposed that silica particles have a direct action on the tissue but rather that silicic acid, produced by the dissolution of the dusts in the tissue fluid, is the direct causative agent. The extensive studies of King (1947) on the solubilities of siliceous materials were largely responsible for the wide acceptance of this solubility theory. King himself emphasized, however, that while the larger part of his data supports such a theory in that more dangerous siliceous dusts are found to be more soluble in water and in physiological fluids, there are many anomalies. Substances which have very high solubilities are apparently harmless but amongst substances in a lower solubility range sandstone, which is known to give a highly dangerous dust, yields less silica in solution than do shales, the toxicity of which is low. Apparently the solubility theory gives a working hypothesis, but other factors may in some instances intervene, and the degree

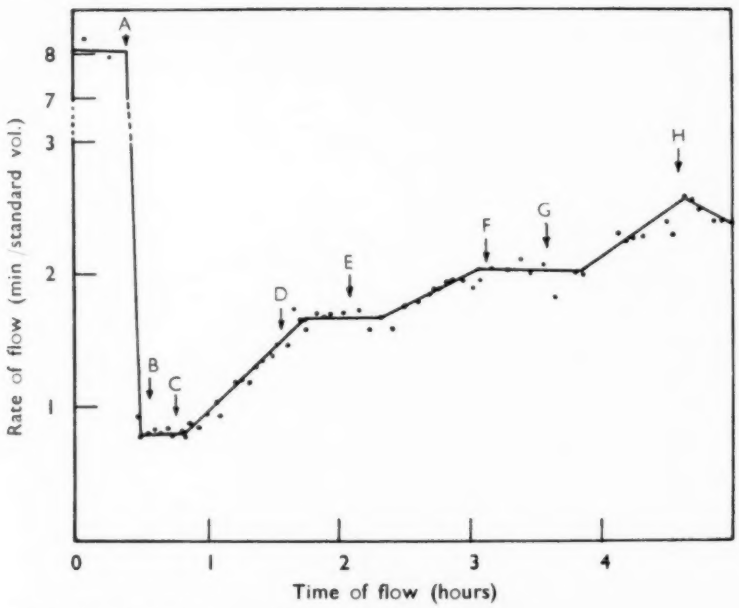

FIG. 1.—Effects of silicic acid on a hyaluronidase-treated membrane.
A = hyaluronidase, B = saline, C = silica sol, 0·002%, aged 24 hours, D = saline, E = silica sol, 0·004%, aged 24 hours, F = saline, G = silica sol, 0·008%, aged 24 hours, H = saline.

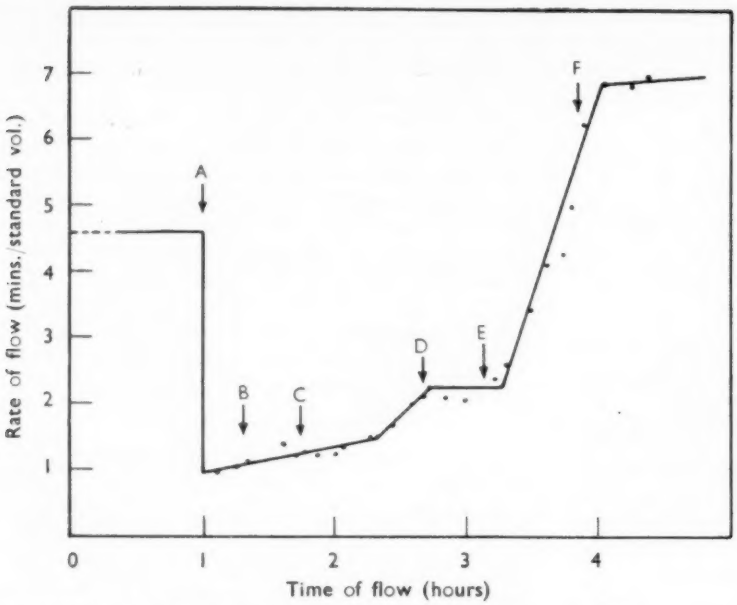

FIG. 2.—Effects of silicic acid on a hyaluronidase-treated membrane. A = hyaluronidase, B = saline, C = fresh silica sol, 0·2%, D = saline, E = silica sol, 0·2%, aged 2 hours, F = saline.

of pathogenicity of a dust may then be completely different from that which would be deduced from its solubility alone.

Our experimental work has shown that silicic acid sols, so dilute that they have viscosities little different from that of saline, contain particles capable of reducing the permeability of tissue which has been treated with hyaluronidase. This indicates that in forming fibrotic tissue silicic acid may act as a filling material in the collagen network and may organize the fibrils, acting in a manner analogous to mucopolysaccharides. The inactivity of sols which had been allowed to polymerize for only a short time would then mean that silicic acid polymers below a limiting size are incapable of initiating fibrosis. This hypothesis of the formation of silicotic tissue requires not only the solution of the dust but also subsequent polymerization of the silicic acid which is formed.

During the last 25 years knowledge of the chemistry of silicic acid has increased rapidly. The statement made in Gye and Purdy's (1922) classic contribution to the silicosis problem that two distinct types of silicic acid exist is now known to be erroneous. Silica dissolves in water to produce orthosilicic acid, $Si(OH)_4$, a substance which begins immediately to polymerize (Willstätter, Kraut, and Lobinger, 1929). It is generally believed (Carman, 1940), that the polymerization is a condensation, proceeding thus :

$$\begin{array}{l} \text{OH} \\ \text{— Si — OH} \\ \text{OH} \end{array} \quad \begin{array}{l} \text{OH} \\ \text{HO — Si —} \\ \text{OH} \end{array} \rightarrow \quad \begin{array}{l} \text{OH} \\ \text{— Si — O —} \\ \text{OH} \end{array} \begin{array}{l} \text{OH} \\ \text{Si —} \\ \text{OH} \end{array} + H_2O$$

Polymerization, which can continue until very large molecules are formed, is most rapid at *p*H 5·5–6 and the rate quickly decreases either side of this value. This was shown by Treadwell (1935) who measured the time necessary for sols of silicic

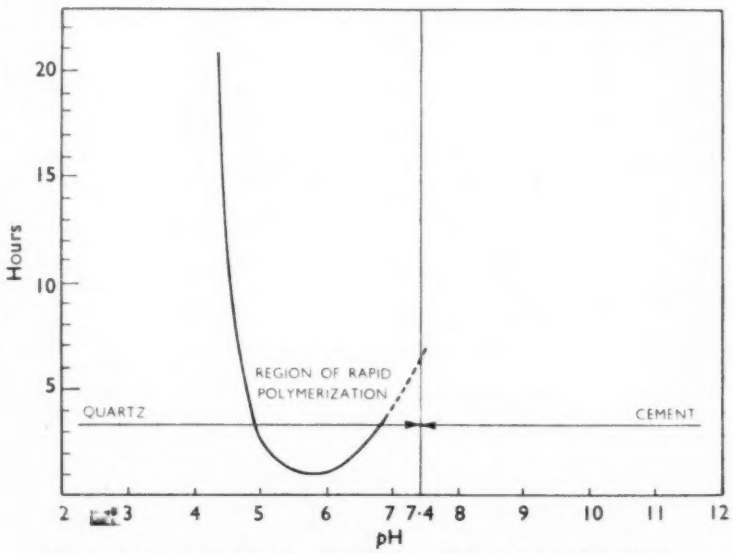

FIG. 3.—Variation with *p*H of the rate of gelling of silicic acid (Treadwell, 1935).

acid at different *p*H values to polymerize to gels. In the light of present knowledge of the chemistry of silicic acid, the probable fate of quartz and cement dusts in the lung will be considered. The effects are represented diagrammatically in Fig. 3, which includes Treadwell's measurements on the polymerization of silicic acid.

When a silica particle makes contact with tissue fluid in the lung the particle dissolves and orthosilicic acid is formed at a very low *p*H. The *p*H has been studied (Elton and Benton, 1953) by measuring the rise in the conductivity of conductivity water when in contact with powdered vitreous silica. The bulk solution has a *p*H of 4·8–5·1 corresponding to a surface *p*H of 1·8–2·1, assuming an electrokinetic potential at the surface of 177 mv. (Wood, 1946). In pure water the change in *p*H from about 2 at the surface of the particle to that of the bulk solution occurs over a distance of about 0·1 to 0·2 microns, but over a smaller distance in salt solutions. At the low *p*H silicic acid polymerizes extremely slowly. The small orthosilicic acid molecules immediately formed by dissolution of silica will diffuse rapidly from the silica particle. In the heavily buffered tissue fluid the *p*H is brought rapidly to 7·4, the silicic acid passing through the region of rapid polymerization. Large polymers will then occur a short distance from and circumferentially around the silica particles, but as the rate of diffusion of a particle in solution is inversely as its size, only the smaller polymers will diffuse beyond this region. The expected distribution of the silicic acid in the zones around the dust particle will then be (Fig. 4) a central zone, B, immediately surrounding the silica particles containing orthosilicic acid and low polymers, a surrounding area, C, containing highly polymerized silicic acid and an outer zone, D, in which smaller polymers exist in lower concentration.

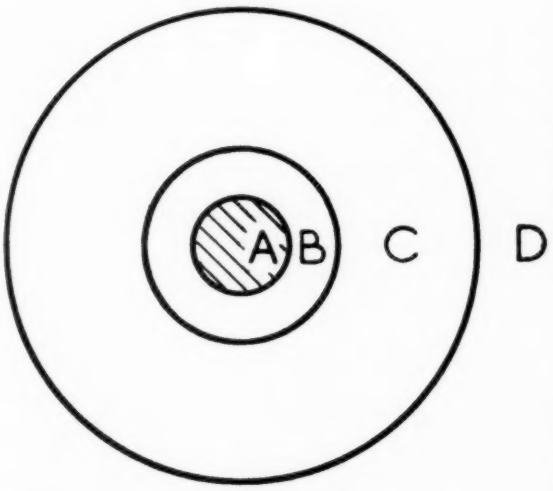

FIG. 4.—Distribution of silicic acid around a silica particle.
A = silica particle, B = small polymers of silicic acid, C = complex polymers of silicic acid, D = low concentration of smaller polymers.

These zones of silicic acid exactly follow the arrangement of the collagen fibres in the silicotic nodule. Middleton (1921) described the concentric arrangement of fibres around the dust particle. "The densest fibrous tissue is near to the centre (zone C) and is surrounded by a less dense region of younger fibrous tissue (zone D). The centre of the nodule (zone B) is looser in texture, less definite in structure and has the appearance of breaking down in a way which suggests what occurs in tumours." Middleton suggested that the centre was necrosing.

Cement dust has not been shown to cause fibrosis but it dissolves *in vivo* (Holt, 1950) and yields a high concentration of silicic acid. Cement is an alkaline dust. The silicic acid which it releases in the tissue is brought to *p*H 7·4 from a higher *p*H value. At no time does the silicic acid enter the *p*H range in which polymerization is rapid, and consequently the polymers necessary for the production of collagen fibres are not formed. The high concentration of low molecular weight silicic acid is eliminated through the kidneys or is detoxicated by mechanisms discussed earlier (Holt and Yates, 1953).

By considering polymerization as a factor in the process of fibrogenesis initiated by silicic acid, it is possible then to explain the contrast between the pathogenic nature of silicic acid formed *in vivo* from dissolving silica and the inertness of silicic acid formed by the dissolution of cement. The extension of this theory to other dusts will require an examination of the surface properties of other siliceous substances.

Summary

Silicic acid is capable of reducing the permeability of membranes treated with hyaluronidase. Its function in fibrogenesis is considered to be analogous to that of the mucopolysaccharides. By considering that the formation of fibrotic tissue requires (1) the dissolution of dust in the tissue fluid, and (2) the polymerization of the silicic acid formed, an explanation is given of the pathogenic effects of free silica dust and the harmless nature of cement dust.

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THE INCIDENCE OF PEPTIC ULCER AND CHRONIC GASTRITIS AMONG SWEDISH SEA PILOTS

BY

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The aetiology of peptic ulcer has for a long time been the subject of lively debate, and various causes have been assumed to contribute to the occurrence of this disease. Among these causes may be mentioned the hereditary factor, the importance of which has been pointed out by Doll and Buch (1950). Attention has been drawn to harassing work and irregular meals as contributory causes of ulcer by several writers, including Hill (1937), Sällström (1945), and Doll, Avery Jones, and Buckatzsch (1951). Shift work and housing conditions have also been discussed in this connexion by Bjerner, Holm, and Swensson (1948) and by Thiis-Evensen (1949). The following report is a preliminary communication on the incidence of ulcer and gastritis in Swedish pilots.

Present Investigation

We have had an opportunity of investigating 416 Swedish pilots in respect of the occurrence of gastric ulcer, duodenal ulcer, and chronic gastritis, and also of considering the hours of work in different pilot stations.

The coast of Sweden is divided into six pilot duty districts with 83 stations in all. Because of the nature of the work the pilots serve, with very few exceptions, at only one station. At each station a head-pilot or a pilot foreman acts as chief. There are two main types of pilot duty, harbour and long-distance. In addition men may serve on cruising pilot-cutters.

The pilot service is so organized that one of the men, the man first in turn on the list, must always be in or near the watch-room to be ready to turn out at a moment's notice. The other pilots follow on the list as second, third man, and so forth, in turn. In actual practice at stations where the burden of work is heavy the second and third men on the list are often forced to remain in the watch-room, as the boats may come in in quick succession, and it may often happen that the pilot is on the list as first or second man as soon as he has completed a tour of duty. A study of the pilots' log-books shows that with only a few hours' sleep a pilot may be on duty for two or three days. As may be seen from the following table, however, there are very great differences in the work at different stations.

To ascertain the incidence of ulcers in the Pilot Service, all the regular pilots on the active list were sent a questionnaire in which they were asked among other things whether they had been in hospital or had consulted a physician, for any gastric affection. If this had been the case information was sought, where possible, from the physician, the sick-relief branch of the Pilot Service, and the hospital.

TABLE

Pilotage Port or Place of Duty	Number of Men	Average Working Hours in Hours per Day-and-night					
		Pilot Duty on Ships	Duty on Pilot-boat e.g. Look-out and Plot-ting	Trip to and from Harbour to Pilot Duty	Watch-room Hours (at the ready)	Hours on Call at Home	Total Hours
Sandhamn	17	1·2	3·5	2·5	7·0	5·8	20·0
Stockholm	17	2·6	0·1	6·3	2·2	7·8	19·0
Norrköping	5	1·7	0·2	6·5	—	11·3	19·7
Ronehamn	1	0·1	7·4	0·1	—	6·8	14·2
Påskallavik	2	0·1	6·6	0·2	—	—	6·9
Fagervik	2	0·2	5·2	0·5	1·6	0·2	7·7

A diagnosis of ulcer or of a relapse was accepted only when it had been verified by radiographs or when the patient had had a haematemesis and symptoms of an ulcer. A diagnosis of chronic gastritis was accepted where the pilot had been examined and this condition had been diagnosed by a physician.

Results

The questionnaire was sent to 416 pilots, all of whom replied. The majority had been employed for more than 10 years and a large group for over 20 years (Fig. 1).

Distribution by age showed that the largest group was between 41 and 50 years (Fig. 2).

There were among these 416 men 40 who had had peptic ulcers, the first case being in 1923 and the last (three cases) in 1951. Among these 40 men there were 16 relapses. Altogether 33 men had had chronic gastritis. The average age of onset of peptic ulcer was 38·1 years, and for that of chronic gastritis, 40 years. Thus 73 cases of chronic gastric affection had occurred among the regular pilots on the active list, which gives a morbidity of 17·5% (ulcer 9·6% and chronic gastritis 7·9%).

It was only possible to calculate the annual morbidity for ulcer and gastritis for 1950, during which year all the employed pilots were contacted. During 1950 six pilots had their first diagnosed ulcer (the average age of onset was 44·7 years), while among the others there were four relapses (average age 42·5 years) and four cases of chronic gastritis (average age 50·5 years); that is to say, a total morbidity of 3·37%, 2·40% for ulcer and relapse, and 0·97% for gastritis alone.

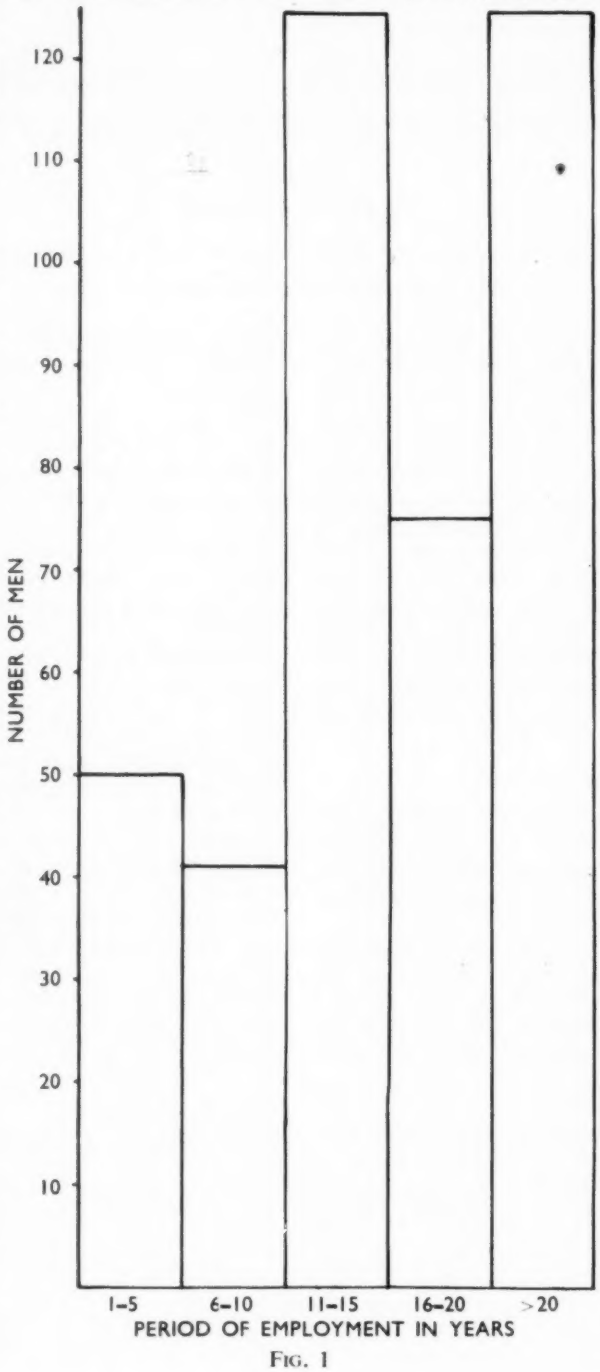

FIG. 1

As it would have been of great interest to compare the morbidity during different years, attempts were made to contact the pilots who had either been pensioned or retired for some other reason during the years 1940–49. This proved difficult, however, and the percentage of replies was so small that it was not possible to make any comparison.

The total number of pilot duties for the years 1925–51 was taken as the criterion for the pilots' burden of work (Fig. 3). Fig. 3 shows that the number of pilot duties was considerably increased during the first year of the second world war (1939) compared with the preceding years. It also shows a rise during the five years immediately following the war. As it was only possible in exceptional cases to take on extra staff, and the number of pilots was thus on the whole constant during the period 1939-50, it is evident that during and after the war the men have been exposed to a marked increase in their burden of work.

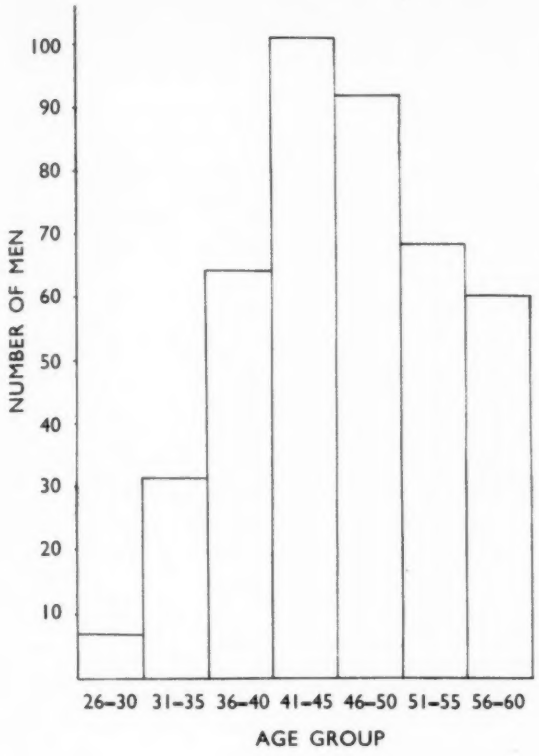

FIG. 2

Since there are considerable differences in the burden of work at the different pilot stations, information was sought from the head pilot officers in all districts concerning their personal opinion of each station from this point of view. At those stations (32) considered by the head pilot officers to be overburdened, 262 men have been employed, of whom 31 and 26 have for the first time contracted a peptic ulcer and chronic gastritis respectively (11·8% and 9·9%). Those pilot stations considered to have an easier burden (51) employed 154 men, of whom nine have or have had ulcers, and seven gastritis, i.e., 5·8% and 4·5% respectively. This difference between the frequency of gastric affections for two groups is statistically significant ($P<0.02$). As the two groups are very similar in respect of age and duration of employment, it seems that the higher ulcer morbidity in the one group may be caused by its pilots being overburdened with work.

Housing conditions for the pilots seem to be good. The average number of rooms per family is three for all the pilots questioned, with an average of 1·5 children living at home.

There is no statistically significant difference in the housing standards of the pilots suffering from ulcer and the rest of the group.

Discussion and Summary

In order to judge whether there is any reason for morbidity in respect of chronic gastric affection among these pilots, comparative material from a male population in the same age group and with the same age distribution is necessary. As far as we are aware, no such material has been published.

Among the studies already mentioned, those of Doll, Avery Jones, and Buckatzsch, and of Thiis-Evensen provide populations which are nearly comparable with ours. In a group of 60,000 males aged 15 to 64 years Doll and Buch found 5·8% had had peptic ulcers, and among 3,058 men Thiis-Evensen found 4·0% with chronic gastritis. The corresponding figures for the pilots in the age group 26–60 years are 9·6% with ulcers and 7·9% with gastritis. For the pilots, most of whom enter the service at about 25 years of age, ulcer has been recorded only if it

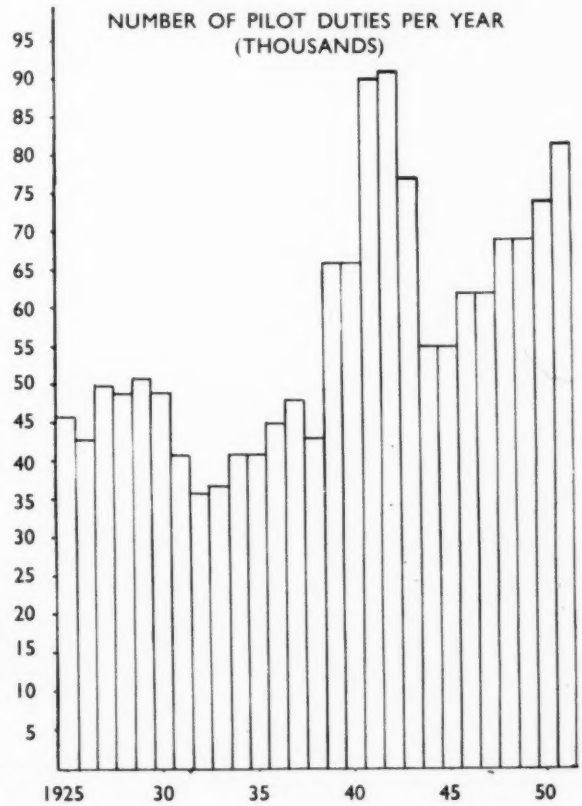

FIG. 3

occurred during the period of employment in the Pilot Service, whereas Doll and Buch have included cases from the whole life time of individuals in the age-group 15–64 years. The figures for the total occurrence of ulcer among the pilots are thus minimum figures.

Bjerner, Holm, and Swensson (personal communication) have determined the annual morbidity for peptic ulcer among 200,000 male annual subscribers to an urban sick-relief fund (Stockholm), finding it to be highest in the age-group 50–65 years with 1·43%, and also among 30,000 male annual subscribers to provincial sick-relief funds, finding in the corresponding age group a morbidity of 0·7%. In the age group 40–49 years the annual morbidity for the city was 1·33% and for the country 0·61%.

Among the pilots we were able to observe the morbidity for the year 1950 only. It was 2·40% for ulcer diagnosed for the first time and for relapses. Although these groups are not strictly comparable with ours, it appears that morbidity from peptic ulcer is high among pilots.

With the significantly higher incidence of peptic ulcer and gastritis among the men in those stations where the burden of work is heavy, it seems that the exacting duties of the pilot service, with irregular working hours and meals and increased duties during and after the war, have been contributing causes of this high morbidity.

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ACUTE POISONING CAUSED BY INGESTION OF ETHYLENE CHLOROHYDRIN*

BY

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From the Institute of Insurance and Legal Medicine of the University of Bologna

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It is thought of interest to report a fatal case of poisoning caused by the ingestion of ethylene chlorohydrin. Cases of poisoning by this substance through the gastro-intestinal tract have not previously been recorded except for two deaths from drinking a solvent mixture containing 25% of ethylene chlorohydrin (Güthert, 1944).

Ethylene chlorohydrin (glycol chlorohydrin, chloroethyl alcohol), $CH_2Cl\text{-}CH_2OH$, is a colourless mobile liquid, with an odour resembling that of a mixture of alcohol and ether. The chlorohydrins or halohydrins are derived from dihydric and polyhydric alcohols, in which the halogen atom replaces a hydroxyl group ; they are stable compounds. Ethylene chlorohydrin is generally obtained by the action of hypochlorous acid on ethylene.

It has an extensive field of application ; it is used as an intermediate product in the preparation of many chemical compounds as an industrial solvent, in the manufacture of a number of insecticides, as a fixative in the colour printing of textiles, for degreasing machinery, and in the treatment of potatoes, particularly sweet potatoes, before sowing in order to hasten germination.

Toxicity

Ethylene chlorohydrin is among the most toxic of industrial solvents and is absorbed through the lungs, skin, or digestive tract. It has an irritant effect on the eyes and nasal mucosa. Cases of intoxication were reported by Koelsch (1927), Middleton (1930), Dierker and Brown (1944), and Goldblatt and Chiesman (1944), and were caused by inhalation of the vapour and perhaps also by concomitant absorption through the skin in the cases reported by Dierker and Brown and by Middleton. Goldblatt (op. cit.) demonstrated its cumulative toxicity and the greater sensitivity of women and debilitated individuals to its action, and suggested a maximum permissible concentration in atmospheric air of 2 p.p.m.

The symptoms of intoxication consist of nausea, vomiting, headache, drowsiness, vertigo, staggering and incoordinated gait, numbness of the extremities, and visual disturbances. Larger amounts of the poison produce hyperexcitability progressing to delirium ; the pulse becomes thin and weak, and the blood pressure extremely low ; there is generalized sweating, and finally circulatory collapse and coma. There may be loss of consciousness and spastic contractions of the hands and arms. Erythematous rashes often appear on the arms and trunk ; there may also be albuminuria and haematuria. Death occurs from cardiac collapse and pulmonary oedema. After death, in addition to pulmonary oedema with much blood in the alveoli, there is congestion of the cerebral cortex with marked oedema of the cerebral hemispheres ; the liver is very congested and also the kidneys, with haemorrhages and tubular degeneration.

The risk of poisoning at work occurs mainly as a result of the possibility of absorbing ethylene chlorohydrin in the form of vapour, but it may occur also by contact through the skin, when, in certain operations, the clothing of the workers becomes impregnated with it. Its toxicity by the cutaneous route has been found equivalent to that by mouth (Smyth and Carpenter, 1945).

Case Report

The fatal case of poisoning described here occurred in a young man aged 26 employed at a chemical works, who, while decanting ethylene chlorohydrin from one vessel to another, acted hastily, and instead of using the

* Translated from the Italian by Dr. L. G. Norman.

proper emptying pump, took an ordinary rubber tube and aspirated the fluid by mouth, although he well knew the poisonous nature of ethylene chlorohydrin and the container was marked with a label carrying the word "poison" and the skull sign. He felt his mouth fill suddenly with the fluid. He immediately spat it out, then rinsed out his mouth with water, and drank several mouthfuls of water. This took place at about 8.15 a.m. About half an hour later he experienced nausea, retching, and headache, and went to hospital. He was seen immediately on admission, at about 10 a.m., when there were present pallor, retching, and a degree of mental excitability. He was still fully conscious. His general condition was considered to be satisfactory and in no way alarming. There was no congestion or any other appreciable lesion in the mouth or pharynx. He was given a sedative ("luminal"), put to bed, and appeared to become quiet and drowsy. After about two hours, at approximately 12 noon, he jumped out of bed suddenly in the greatest excitement and quickly became almost maniacal: he was swearing, spitting into the air, shouting, and after a sharp and violent struggle with the nurses who were trying to restrain him, he suddenly threw himself down on the bed and almost immediately became comatose, with complete absence of reflexes. There was profuse sweating, and cyanosis followed pallor; the pupils were small and fixed, and all the signs of collapse followed. After hypodermoclysis and the injection of cocarboxylase, there was an apparent improvement and the reflexes reappeared. His condition remained stationary for a time and then suddenly worsened; the pupils again became myotic, while still responding to light, and towards 3.30 p.m. he suddenly experienced generalized tetanic convulsions and the respiration and cardiac contractions ceased, presenting the picture of a bulbar paralysis. Artificial respiration and the intracardiac injection of adrenalin were without effect.

Post-mortem Examination.—The body was of good skeletal formation and excellent muscular development. Rigor mortis was present, and rather marked, dark, hypostatic staining on the back of the body, extending also to the sides. The body was generally well preserved, but over the abdomen a greenish discoloration was already appearing. The natural orifices were dry. There was no particular odour from the body.

Head.—The brain and meninges were markedly congested, particularly when examining the meningeal linings. The meninges were free from any lesions or signs of disease, but the brain was translucent on account of moderate oedema. Section of the various parts of the brain did not reveal even punctiform haemorrhages or softening.

Neck and Thorax.—There were no signs of irritation or other lesion in the posterior parts of the mouth, the larynx, pharynx, or upper part of the oesophagus. The thyroid was normal in size and appearance. The thymus, of a reddish colour, was rather large for the age of the individual and very congested (35·5 g.).

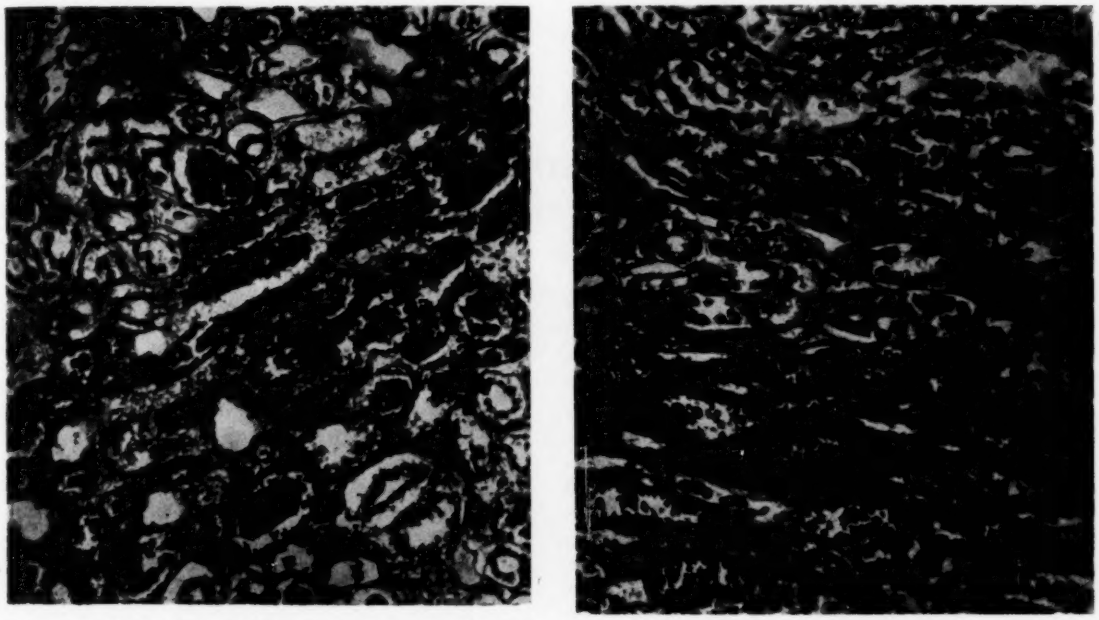
The pleura was smooth and shiny, as also was the pericardium; there was a small quantity of yellow fluid in the pericardial sac. The heart was of normal size in relation to the heavily built body and was anatomically normal. On the posterior aspect of the heart were numerous punctate haemorrhages (Tardieu's spots).

The lungs were very bulky. From the cut surfaces exuded abundant quantities of reddish, frothy fluid, and from the mouths of the cut vessels poured dark, thick blood. The red, frothy fluid filled not only the lungs but the lower air passage also. A number of Tardieu's spots were noted on the surface of the lungs. The frothy fluid from the lungs was acid in reaction.

Abdomen.—The lower part of the oesophagus showed no irritation or signs of any other lesion. The stomach contained about 10 ml. of reddish turbid fluid with the characteristic odour of normal gastric contents. The gastric mucosa showed many superficial haemorrhagic effusions. The liver was very congested; its size, consistence, and colouring were normal. The spleen was a little enlarged, with somewhat tense capsule. The left kidney was much reduced in size, with a very uneven surface, and was covered with a thickened capsule which was very closely adherent to the underlying parenchyma. The parenchyma was reduced to a few trabeculae, and between these were cavities, empty or nearly so, surrounded by a very thick, whitish fibrous tissue lining. The ureter of this kidney was much narrowed and transformed into a cord-like structure. The left suprarenal was also much smaller than normal, but was of normal shape and showed no appreciable macroscopic changes. The right kidney was almost double a normal kidney in volume; its capsule peeled easily. The relative amounts of cortex and medulla appeared to be normal. The size of the ureter was adequate for the size of the kidney. The right suprarenal was also larger than the left. The bladder contained a few cubic centimetres of turbid urine which had a neutral reaction.

Histological examination of the pharynx did not reveal any evidence of irritation. Hyperaemia was generally observed in the preparations of the various organs. In the right kidney and the functioning part of the left were seen, in addition to congestion, haemorrhagic extravasations both in and surrounding the tubules (Figs. 1 and 2) and a moderate oedema of the glomerular and tubular epithelium.

Estimation of Ethylene Chlorohydrin in Blood and Urine.—For the determination of ethylene chlorohydrin in the blood and urine, because only a small quantity of urine was available, the micromethod of Widmark was used. A simplified Widmark apparatus was used for the determinations, as described by Smith and Glaister (1939), using the same technique for ethylene chlorohydrin and taking care to carry out the distillation at about 130° C. in order to ensure the complete oxidation of the ethylene chlorohydrin. With this method a concentration of ethylene chlorohydrin of 27·89 mg. % was found in the blood and



FIGS. 1 and 2.—Sections of kidney showing haemorrhagic extravasations both in and surrounding the tubules and oedema of the glomerular and tubular epithelium.

80·49 mg. % in the urine. The difference in concentration of ethylene chlorohydrin between blood and urine is similar to that found with ethyl alcohol.

The clinical symptomatology and the pathological and histological examination suggest that in this case death occurred through cardiac and circulatory collapse, pulmonary oedema, and involvement of the central nervous system, and the toxic picture resembled that of acute ethyl alcohol poisoning. The toxic action was particularly effective on the blood vessels, causing an intense hyperaemia of all organs and irritation of the bulbar centres, terminating in bulbar paralysis.

Summary

A fatal case of poisoning caused by the ingestion of a small quantity of ethylene chlorohydrin is described. Death occurred after seven hours, the symptoms consisting of nausea, retching, headache, excitability, delirium, coma, and collapse. Death was apparently due to cardiac and respiratory collapse. Post-mortem and histological examination showed no changes in the mouth and pharynx; hyperaemia of various organs, particularly of the brain and meninges, and of the liver; marked oedema of the lungs; and extravasation of blood, congestion, and oedema, in and around the renal tubules.

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NIGHT WORK AND SHIFT CHANGES

BY

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It is generally recognized that night work is undesirable and is only permissible when strictly necessary, as in some continuous operations or in times of emergency. Objections to night work have been made on medical, social, and economic grounds, and the latter aspects of the problem were studied in some detail by the Health of Munition Workers Committee (1918) during the 1914–18 war. This Committee found no significant difference between the rates of output of men employed on alternate day and night shifts and recommended this system in preference to continuous night work. Alternate day and night work was also shown to be only slightly inferior, as regards output, to continuous day work, while from the standpoint of lost time it was better than day work.

These findings refer mainly to a weekly change of shifts but in many factories shifts are changed every fortnight and in some every month. The frequency of shift changes is clearly a matter of some importance, but evidence of the effects of these changes and their relation to the problems of night work is very meagre. Some figures collected by Vernon for the Health of Munition Workers Committee (1917) showed that, when shifts were changed fortnightly, output was slightly higher and absenteeism less during the first week on the night shift than during the second week. The corresponding figures for the day shift showed, if anything, the opposite tendency.

In a survey of the literature relating to the effects of night work on health and efficiency Teleky (1943) concludes that night work causes an inversion of the body temperature curve which, for most factory workers, takes place within a week. After changing back to day work the reversion to normal is more rapid than the inversion. Teleky thinks that these periods of inversion and reversion of body temperature may be associated with increased physiological strain and tentatively suggests a monthly rather than a weekly change of shifts. The Health of Munition Workers Committee also emphasized the physiological advantages of infrequent shift changes but recognized that it might be difficult to reconcile these advantages with personal desires and social claims.

This paper describes a preliminary study in which we attempted to define more precisely the nature of the factors involved in night work and shift changes and to indicate their probable effects. It was realized at the outset that conclusive evidence could only be obtained by studying the same group of workers employed on different shift sequences but the facilities and conditions necessary for such a study could not be found. As an alternative, it was decided to conduct a limited inquiry in three factories (A, B, and C) having a weekly, a fortnightly, and a monthly change of shifts respectively and so to prepare the way, if necessary, for a more extensive investigation later. The inquiry was limited to male workers and most of the information was collected in 1945–46. Factory A made railway wagon wheels, factory B was a rolling mill, and factory C made motor vehicles.

The general procedure was to collect all the available records of output, accidents, and absence from work which might provide reliable information on the merits and defects of night work and the frequency of shift changes. In addition, a number of men in each of the three factories were interviewed in order to ascertain their attitudes to various aspects of the problem.

Output

Output records should show the relative efficiency of day and night work and also whether efficiency increases or decreases for some time after the change of shifts. In order to demonstrate these possibilities, it is necessary for individual workers to be employed on the same process throughout the experimental period. Further, the cycle of operations for each unit of output must be fairly short, easily measurable, and reflect working capacity. In this investi-

gation very few of the processes were found to satisfy these conditions. An exhaustive search in the three main factories yielded output records from a small number of men in Factory A, none in Factory B, and a few specially recorded figures in Factory C ; hence the amount of evidence included in this section fell far short of expectations. It has, however, been supplemented by a few output figures collected from groups of workers employed on machining operations in other factories.

A general comparison of the average hourly output on day and night work is given in Table 1.

TABLE 1

RELATIVE HOURLY OUTPUT OF MEN ON DAY AND NIGHT SHIFTS OF THE TWO-SHIFT SYSTEM

Factory Group	Shifts Changed	Length of Period (weeks)	No. of Workers	Relative Hourly Output*	
				Day Shift	Night Shift
A	Weekly	16	41	99·97	100·03
D	,,	8	16	100·81	99·19
E	,,	18	82	100·46	99·54
Average of 3 factory groups			.. ..	100·41	99·59
F	Fortnightly	8	105	100·17	99·83
G	,,	8	72	101·13	98·87
H	,,	4	75	100·25	99·75
I	,,	4	53	99·88	100·12
Average of 4 factory groups			.. ..	100·38	99·64
C	Monthly	8	45	101·13	98·87
J	,,	8	41	100·47	99·53
K	,,	8	25	100·71	99·29
Average of 3 factory groups			.. ..	100·77	99·23

*Expressed as a percentage of the average hourly output on both shifts combined.

The figures show that the average hourly output was slightly higher on the day shift than on the night shift. In each factory group the weekly hours of work were approximately the same on both the day and night shifts but as there were five and a half day shifts and five night shifts per week the daily hours were usually a little shorter on the day shift than on the night shift. The average hourly output on Saturday morning was from 11 to 15% less than the average from Monday to Friday, and the exclusion of this relatively unproductive period from the day shift averages in Table 1 would increase the difference between the day and night averages. A majority of the workers was also employed on semi-automatic machines which, unlike handwork, fail to reflect the full effect of changes in working capacity on output.

Although the figures in Table 1 show that the rate of working tended to be higher on the day shift than on the night shift, it would be rash to infer that night work was more fatiguing than day work. It may be, but the lower rate on the night shift could also be due to other factors. There is a fairly widespread belief, and some of the figures collected in this inquiry support the view, that many workers aim at a fixed weekly wage and regulate their output accordingly. Such workers could afford to reduce their rate of working on the night shift and yet earn the same weekly wage because of the higher basic rate.

Nevertheless a substantial majority of the workers in each factory group consistently produced more per hour on the day shift than on the night shift. Most of the remainder consistently showed the opposite tendency. Further, out of a total of 150 men who were closely questioned on their attitude to day and night work, 68% claimed that they worked better on the day shift than on the night shift ; 21% noticed no marked difference, and the remaining 11% found the night shift better for output. The attitude of these men to day and night work seemed to be closely related to the disturbing effects of night work on eating and sleeping habits ; the greater the effect, the stronger was the preference for day work. These observations support the hypothesis that, to a majority of workers, night work needs more effort and is more tiring than day work and hence strengthen the probability that the differences in Table 1 were due to increased fatigue on the night shift. The differences in question may, however, disappear if the night worker is able to get enough sleep and can enjoy and digest his food.

In the four factories (F, G, H, and I) with fortnightly changes of shifts, the average hourly output in the first and second weeks after the change are compared in Table 2.

TABLE 2

RELATIVE HOURLY OUTPUT IN THE FIRST AND SECOND WEEKS AFTER THE CHANGE OF SHIFTS

Factory Group	No. of Workers	Relative Hourly Output*					
		Day Shift			Night Shift		
		1st Week	2nd Week	Average	1st Week	2nd Week	Average
F	105	99·22	101·13	100·17	98·22	101·43	99·83
G	72	99·48	102·77	101·13	98·52	99·23	98·87
H	75	99·83	100·67	100·25	99·50	100·00	99·75
I	53	99·76	100·00	99·88	100·82	99·42	100·12
Average of all groups ..		99·57	101·14	100·36	99·26	100·02	99·64

*Expressed as percentages of the average hourly output on the day and night shifts combined.

On the day shift hourly output was higher in the second week than in the first week. The corresponding figures for the night shift were less definite.

It seems highly probable that the lower rate of working in the first week on the day shift was due mainly to the after-effects of a fortnight on the night shift. In other words, the workers not only found it more difficult to maintain efficiency on the night shift but the effects of this effort in the form of reduced working capacity were carried forward to the following week on the day shift.

The results obtained from the three factories (C, J, and K) where shifts were changed every month are given in Table 3.

TABLE 3

RELATIVE HOURLY OUTPUT* IN THE FIRST, SECOND, THIRD, AND FOURTH WEEKS AFTER THE CHANGE OF SHIFTS

	Factory Group	No. in Group	1st Week	2nd Week	3rd Week	4th Week	Average
Day Shift	C	45	99·98	100·61	101·42	102·51	101·13
	J	41	98·79	99·22	100·52	103·34	100·47
	K	25	99·47	100·97	101·04	101·36	100·71
Average of all groups			99·41	100·27	100·99	102·40	100·77
Night Shift	C	45	98·53	98·98	99·62	98·35	98·87
	J	41	98·57	97·59	98·62	103·34	99·53
	K	25	99·92	99·02	99·86	98·36	99·29
Average of all groups			99·01	98·53	99·37	100·02	99·23

*The figures are percentages of the average hourly output on the day and night shifts combined.

The day-shift figures show that the average hourly output increased in successive weeks after the change of shifts but the corresponding figures for the night shift revealed no definite tendency. The results accordingly support the view already expressed that the effects of night work impaired the rate of working on the subsequent day shift.

The output records as a whole show that output on night work was lower than on day work, though the advantage in favour of day work, measured in terms of percentage increases in efficiency, was never very large. There was also a fair amount of evidence that a period of two or four weeks on the night shift reduced the rate of working on the subsequent day shift. From these findings it follows that alternate periods of two or four weeks on day and night work are likely to be less productive than continuous day work.

Although most workers produced more output on the day shift than on the night shift, some (about one-third) worked just as well or even better on the night shift. Individual differences of this type should be taken into account when selecting men for night work.

Absence from Work

Since absence from work reflects, among other things, the effects of working conditions, it should provide some indication of the effects of night work and shift changes. A general comparison of the amount of absence on day and night work in different factory groups is given in Table 4. The figures refer to men, employed on various types of engineering, who changed shifts every fortnight.

TABLE 4

ABSENCE* OF MEN ON DAY AND NIGHT WORK

Factory	Length of Period (weeks)	Number Employed		Percentage Absence	
		Day Shift	Night Shift	Day Shift	Night Shift
F	28	2,953	1,097	10·37	7·73
G	20	609	299	7·89	6·19
L	32	2,431	1,196	9·67	8·71
M	12	435	190	11·36	9·07
N	36	857	708	8·73	8·69
O	32	7,582	3,086	8·96	6·93
P	12	507	305	8·25	7·62
Q	20	787	273	7·32	5·40
R	24	739	270	8·30	5·53
S	12	2,415	678	8·05	5·00
Average of 10 factories				8·89	7·09

* Number of shifts lost expressed as a percentage of the number of shifts possible.

In all the factories absence was higher on the day shift than on the night shift. But the day-shift workers were more numerous than night-shift workers because the day shift included permanent day workers as well as day-shift workers of the two-shift system. Since most of the factory records of absence failed to distinguish between these two groups it was impossible to compare the absence of the same men on day and night work in alternate periods.

The inclusion of permanent day workers in the groups of two-shift workers was largely responsible for the higher rate of absence on the day shift since men who were unfit for night work were usually assigned to permanent day work.

The general validity of these beliefs can be confirmed in different ways. In the first place, the excess of absence on the day shift in the different factories was directly related to the excess in the number of workers on the day shift. Secondly, in three factories where it was possible to abstract the absence records of the same men when employed on day and night work in alternate periods, absence on the day shift was only slightly higher than on the night shift.

Other factors which may have a bearing on the absence rates for day and night work are counter attractions outside the factory and the higher rate of payment for night work. For day-shift workers, for instance, any reluctance to go to work is likely to be reinforced by the many and varied opportunities for recreation and amusement but on the night shift the competing distractions are usually less numerous. The higher rate of payment for night work, may, on

the other hand, have different effects on different people. Some will use the opportunity to earn as much as possible while others may act on the principle that the higher rate will compensate for time lost through an occasional absence.

In general, the absence figures for day and night work suggest that although factory records are likely to show an advantage in favour of night work, the advantage tends to become small or insignificant when comparisons are limited to the same workers employed on day and night work in alternate periods. The average weekly attendance on the day shift may also be adversely affected by the relatively high absence on Saturday morning and by competing interests outside the factory.

The figures in Table 5 refer to some of the factory groups included in Table 4 and show the percentage of shifts lost in the first and second weeks of the day shift and night shift respectively. Weeks affected by holidays were not included in these comparisons.

TABLE 5

ABSENCE* OF MEN IN THE FIRST AND SECOND WEEKS OF DAY AND NIGHT SHIFTS

Factory	Length of Period (weeks)	No. Employed		Percentage Absence			
				Day Shift		Night Shift	
		Day Shift	Night Shift	1st Week	2nd Week	1st Week	2nd Week
F	28	2,953	1,097	10·44	10·29	7·47	7·98
L	32	2,431	1,196	9·75	9·60	8·69	8·73
N	36	857	708	9·05	8·40	8·32	9·07
O	32	7,582	3,086	9·14	8·79	6·71	7·14

* Number of shifts lost expressed as a percentage of the number of shifts possible.

The general trend of these figures shows that absence was less in the second week of the day shift than in the first week of this shift. The differences, though small, were statistically significant in Factories N and O and approached significance in Factory F. On the night shift, absence was higher in the second week than in the first week of the fortnightly period, the difference being significant in Factories F, N, and O.

Records of absence were also collected for a period of 16 weeks from 431 men in Factory C who changed shifts regularly every four weeks. Each man had two periods of four weeks on the day shift and two similar periods on the night shift. The average amount of time lost in corresponding weeks on day and night shifts was :

	Percentage Absence				
	1st Week	2nd Week	3rd Week	4th Week	Average
Day Shift	5·38	5·26	5·10	3·96	4·93
Night Shift . .	4·48	4·59	4·83	5·17	4·77

Thus absence in the four successive weeks tended to decrease on the day shift and to increase on the night shift. These opposed tendencies, though based on the records of a comparatively small group, are similar to those obtained when shifts were changed every fortnight.

The most probable explanation of these tendencies is that night work impaired fitness or inclination for work, which resulted in a higher rate of absence in the later weeks of the night shift and in the earlier weeks of the following day shift. The decrease in absence in the second week of the day shift (Table 5) becomes more significant when it is remembered that, in three of the four factories, more than half the workers on this shift were employed on permanent day work and their absence figures would accordingly have a levelling effect on those of the first and second weeks of the day shift.

Accidents

An analysis of the accident records of 13,962 men employed in five factories showed that in each factory the accident rate was slightly higher on the night shift than on the day shift but in no case was the difference statistically significant. It is necessary to remember that night workers, as compared with day workers, are usually less inclined to go to the ambulance room for treatment of minor injuries, especially if the visit involves a walk in the dark and sometimes in rain.

It was also found that the accident rate in each factory varied on different days of the week but the general trends of the variations had little in common. The results accordingly suggest that in these groups the daily changes in accident frequency were due to local influences rather than to some common factor. In other words, the causes of the variations must be sought by detailed studies within each factory.

An accurate assessment of the parts played by speed of production, fatigue, boredom, and other factors in the causation of industrial accidents has yet to be made and a carefully devised and controlled series of experiments is necessary for this purpose. In the present state of our knowledge any attempt to explain the causes of the hourly and daily variations in accident frequency would be largely guesswork.

Attitudes of Workers

Although it is reasonable to assume that any major effects of night work and shift changes will be reflected in records of output, absence, and accidents, these objective indications give only one side of the picture and it is almost equally important to know what the workers think and feel about night work. It is, for instance, often difficult or even impossible

to persuade workers to agree to a change in the methods or conditions of work which, though supported by material evidence, yet fails to coincide with personal feelings and desires. Further, the opinions expressed by the workers are likely to reveal important and unsuspected aspects of the situation that are not disclosed by objective records. For these and other reasons it was decided to interview a sample of 50 men employed on the two-shift system in each of the three main factories, A, B, and C, with a weekly, a fortnightly, and a monthly change of shifts respectively. The men were chosen at random from those who changed from the day shift to the night shift at regular intervals. It was thought that these samples, though small, would be big enough to show general tendencies and that, if necessary, a larger number could be interviewed at a later date. Each interview lasted from 30 to 60 minutes and was conducted in a private room provided by the management. The general aim and confidential nature of the interview were first explained to each worker and the main questions were preceded by reference to such routine details as age, length of service, and type of work. In order to preserve uniformity of procedure and to avoid discrepancies due to individual differences in assessing the results, the questions were standardized and all the interviews were conducted by the same investigator. Almost without exception, the workers showed the keenest interest in the questions.

Shift Preferences.—The men were asked which shift they preferred and to give reasons for their preferences. Almost all the men in each group preferred the day shift. Whether the men were employed on a weekly, fortnightly, or monthly change of shifts seemed to make little or no difference to their choice.

The day shift was preferred by 41% of the men because it left them free to do what they liked in the evening. They mentioned in particular the opportunities for recreation, amusement, and home life. About one-third said they felt better on the day shift and emphasized the advantages of the more normal and restful hours of sleep. A somewhat smaller proportion (20%) spoke of better appetite and digestion and the value of meals at regular times.

The night shift was disliked by 34% of the men because they were unable to get enough sleep during the day and consequently felt tired and listless during the night. About 23% complained of the interference with personal habits and social life and approximately the same proportion referred to digestive trouble. The comparatively few men who liked or did not wholly dislike the night shift seemed to be influenced mainly by the higher rate of payment for night work. Although all the men had been employed for several years on the two-shift system, it is significant that a large proportion said they were still affected by the change in eating and sleeping habits.

The men were also asked if they preferred to change shifts weekly, fortnightly, monthly, or at longer intervals. A large majority (66% in A, 78% in B, and 68% in C) preferred the existing system of shift changes. This agrees with previous findings, and is merely an example of the general principle that workers tend to like what they are used to. Most of the men who preferred a weekly change of shifts said that a week on the night shift was quite enough and a longer period would be too tiring. Some qualified their preferences by saying that a fortnightly change of shifts would give more time to get used to the interference with eating and sleeping habits but on balance they preferred the weekly change. Those who preferred the fortnightly change of shifts thought that a fortnight was better than a week from the standpoint of digestion and sleep and the same reason was given by those who liked a monthly change.

Fatigue.—Objective measures of industrial fatigue are usually based on the assumption that fatigue reduces the speed or accuracy of work and that this reduction is likely to be reflected most clearly in records of output and accidents. It may also be assumed that the cumulative effects of fatigue are sometimes partly or wholly responsible for absence from work. These objective measures, however, give only crude indications of the degree of fatigue and have been used as such in the present inquiry. Because of practical difficulties, no attempt was made to measure the variations in output throughout the day and, apart from the few hourly records of accidents, this study yielded no material indications of changes in working capacity during the daily hours of work.

Some subjective evidence on fatigue was obtained by questioning the men on their feelings of fatigue, and it was found that 8·7% felt most tired on the day shift, 83·3% on the night shift, and the remaining 8·0% noticed no difference. Those who felt most tired on the day shift said it was due to early rising and lateness in going to bed.

The replies to another question showed that feelings of fatigue at the end of work were more widespread and severe after night work than after day work. If fatigue increases as work proceeds, then feelings of fatigue should be most prominent

in the last hour of work. This was found to be so on the day shift but not on the night shift where the peaks occurred between 3.0 a.m. and 4.0 a.m. or about three hours before the end of work. It seems probable that some of the fatigue felt at this stage was due to boredom which was afterwards dispelled by the increasing awareness of the approaching release from work.

The men who changed shifts fortnightly (Group B) and monthly (Group C) were asked if they felt most tired near the beginning or towards the end of the fortnight (Group B) or month (Group C). Their replies showed that men on a monthly change of shifts as compared with those on a fortnightly change included a larger proportion who felt most tired at the beginning of the period when on the day shift and at the end of the period when on the night shift. The inference seems to be that the monthly change of shifts, as compared with the fortnightly change, caused relatively more fatigue towards the end of the night-shift period, which, in some cases, was carried forward to the beginning of the day-shift period.

The few men who felt most fatigued towards the end of the day-shift period said it was due to " thinking about going on the night shift again ", hence in these cases the feelings seemed to be due more to the dislike of night work than to actual fatigue. This attitude was also responsible for some of the increased fatigue felt at the beginning of the night-shift period, e.g.

> " The night shift is lousy and at the beginning I dread the thought of going through a fortnight on night work."
>
> " The beginning is the worst but it is depression as well as tiredness."

When shifts are changed fortnightly or monthly the incidence of fatigue is likely to be influenced by the intervening week-end break or breaks, usually from Saturday morning till Monday night. During these breaks most of the men revert to the normal time for sleep, but as a rule they get up very late on Sunday and later than usual on Monday and have no more rest before they leave for work on Monday night. A few " get up with the family " on Monday and rest in the afternoon. Some of the men found these week-end breaks and longer hours of sleep refreshing but others claimed that they made adaptation to night work still more difficult. The probable effect of these breaks on the physiological rhythms is clearly a matter of some importance and must be taken into account when assessing the merits and defects of night work and shift changes.

Meals.—The change in meal times during night work is believed to disturb digestion. It is also possible that, for some workers, the change may be an important factor in the aetiology of peptic ulcer. Of the 150 men who were interviewed, approximately 70% preferred to bring their own food rather than have the dinner provided by the factory and some of the remainder had the canteen dinner only occasionally. The proportions were roughly the same on both the day and night shifts.

Most of the non-users had tried the canteen meals and then decided in favour of food prepared at home which, in their view, was either superior, cheaper, or suited them better. Some admitted that they were fussy or faddish about food and a few disliked eating in public. A small number (4%) said that the walk to the canteen and the queueing for food made eating " too much of a rush " so that they had no time to rest afterwards. About 25% of the men on the night shift " couldn't face the canteen dinner " and preferred lighter food.

Almost all the men brought sandwiches, which were eaten as snacks during the short breaks by those who had the canteen dinner. The remainder usually divided them roughly according to the time and length of the different breaks.

When asked about their appetites, 74% of the men said they enjoyed their food more when working on the day shift ; 3·3% had better appetites on the night shift, and the remaining 22·7% noticed no appreciable difference. The main reasons given for loss of appetite on the night shift were the " unnatural " meal times and stomach trouble.

About 70% of the men spent from 15 to 30 minutes over their main meal and the rest of the time in sitting, reading, talking, or dozing. Most of the remainder played cards or darts.

Whether shifts should be changed every week, fortnight, or month, will depend, amongst other things, on the effects of these changes on digestion and the time taken to get adapted to the change. The proportion of men who claimed that they settled down immediately to the new meal times after changing *from night to day work* was 61·3%. Most of the remainder took from one to six days and a few took longer. After changing *from day to night work*, only 37·3% seemed to be immune from the effects. A further 27% took from one to three days, 12·0% from four to six days, and most of the remainder never became completely adapted. Of the men in the latter category, 14 were employed for a week at a time on the night shift, six for a fortnight, and 15 for a month.

In view of the effect of shift changes on meal times, it seemed desirable to inquire whether these changes caused indigestion. The proportion was fairly small (31 out of 150) but 23 stated that they

felt it more on the night shift than on the day shift. In 24 cases the attacks were occasional and irregular but in seven cases the indigestion seemed to be continuous. All the men stated that it had never been necessary to give up a job because of stomach trouble but a few (eight) had apparently been on the verge of doing so. It is necessary to remember, however, that the men interviewed were long-service workers and that the most serious cases had either left or been transferred to lighter work on a permanent day shift.

Of the 150 men in the three groups, 65 took patent medicines, usually every day or several times a week. The type of medicines taken suggested that they were in an attempt to counteract disorders of the stomach. Aspirin or similar tablets were also taken fairly frequently by 33% of the men.

Sleep.—In this inquiry, it was found that approximately 75% of the night shift men went to bed before 10 a.m. and about the same proportion got up between 3 p.m. and 6 p.m. The proportion who were satisfied with the amount of sleep was 57·7% but many of these added the qualifying remark that it was less refreshing than night time sleep.

The ability to sleep during the day was made more difficult by noises due to traffic, children, tradesmen, and wireless. About one-third of the men mentioned these disturbing noises while a further 24% attributed their wakefulness to " nerves ", restlessness, fatigue, and bodily discomfort caused by the reversal of normal habits. A few men were able to sleep " like a log " whatever the conditions.

The men were questioned on the time taken to get adapted to the new sleeping habits involved by the change of shifts. Their replies showed that a large majority (83·3%) adapted themselves immediately to the normal time for sleep after changing to the day shift. The corresponding figure for the night shift was 50%. On the whole, the change in sleeping times seemed to be less disturbing than the change in meal times.

General Considerations

The output records collected in this survey showed no spectacular differences between the average rates of working on day and night shifts, neither were there any substantial changes in weekly efficiency within the shift cycles when shifts were changed every fortnight or every month. Yet there was little doubt that a majority of the workers found it more difficult to maintain their usual level of efficiency on the night shift than on the day shift.

Several of the tendencies shown by the output records were supported by the rates of absence on day and night work. Thus, after changing from night work to day work, attendance improved during the fortnight or month on the day shift. This, like the output records, suggests a process of recovery from the effects of night work and hence implies that night work imposed additional strains on the workers. Further evidence in support of this hypothesis was provided by the absence figures for the night shift which, unlike the day-shift figures, tended to increase in successive weeks.

The opinions of the workers on various aspects of night work were more illuminating than the factory records and it was rather surprising that what they felt seemed to have comparatively little effect on what they did. It must be remembered, however, that these men were employed on semi-automatic processes which tended to mask variations in working capacity. Also, their daily output was largely determined by long-established habits of work. Sometimes the cumulative effects of night work had repercussions on life outside the factory, and sometimes a stage was reached when a man had to be put on permanent day work but on the whole the feelings induced by night work seemed to be inadequately reflected in output. Feelings are often in conflict with necessities and a distaste for night work may be kept in abeyance by monetary needs. It is only when feelings reach a certain stage of intensity that they have an observable effect on rate of working.

Most of the men included in this survey mentioned the disturbing effects of changing from day work to night work on appetite and digestion and only a minority claimed that the change had little or no effect. The gradual process of adaptation to the change in meal times is, of course, one of the main arguments against a weekly change of shifts. It is interesting to note that more than 70% of the men, although employed on fairly heavy work, ate nothing but sandwiches while in the factory and many had only a light meal before starting work. There can be little doubt that, quite apart from the irregular meal times, the diet of most men was unbalanced and in need of some adjustment. As far as could be ascertained, they received no guidance on this subject either inside or outside the factory.

Many night workers referred to their inability to sleep well during the day, especially in the period immediately following the change of shifts. Even under the most favourable conditions, the reversal of normal habits tended to impair both the quantity and the quality of sleep but for many there were additional disturbances such as day-time noises. The inability to get enough sleep, especially during the first few days after changing shifts, is a further argument against a weekly change of shifts.

The interference with sleep and digestion is perhaps the most obvious and expected effect of night work and shift changes. The human body is a complicated and balanced mechanism which, when properly nourished and rested, continues to function in a smooth and effortless manner. Any marked deviation from the normal mode of life, such as the reversal of eating and sleeping habits, will naturally disturb the physiological rhythms and impose additional strains on the body mechanisms. Although the human machine is very adaptable there are limits to what it can bear and it is probably not surprising that some men were sorely tested by the change from day to night work. These physiological disturbances are, however, not the only adverse effects of night work ; they are sometimes equalled or exceeded by psychological stresses and strains caused by the disruption of social and family life. Most men and women have fairly fixed habits and dislike any change in their daily or weekly routine. Evening and week-end interests and activities are often the only high lights in a rather colourless existence and anything that interferes with these pleasures is usually strongly resented. Even more serious in their effects are the mental and emotional conflicts caused by the dislocation of normal married life. Several men referred to this problem and their comments varied from the comparatively mild opinion that " a week is quite long enough for the wife to be left alone at night " to admissions of strained or broken marital relations which were accentuated, if not caused, by night work.

This survey disclosed marked individual differences in susceptibility to the effects of night work and shift changes. While some experienced only mild discomfort and worked just as well on the night shift as on the day shift, others were more upset by night work. It is important to remember that the men included in this inquiry were long-service workers hardened by experience. They accordingly represented a selected group since those who were unable to bear the strains of night work had been transferred to permanent day work or discharged. An attempt was made to ascertain the number of men in each factory who, for health reasons, had been exempted from night work, but the records were incomplete, inaccessible, or non-existent. The exclusion of these men from the present survey means that the adverse effects of night work and shift changes, as well as individual differences in response to these conditions, will be underestimated. Yet the findings show that some men were still unable to adapt themselves to night work and were obviously unsuitable for work on a two-shift system. In general, the results suggest that more attention should be given to the selection of men for night work and to the closer medical supervision of those selected.

With regard to the question as to whether shifts should be changed weekly, fortnightly or monthly, the evidence obtained in this inquiry, like that of earlier investigations, was inconclusive. While there can be little doubt that, for most workers, the change from day to night work had unfavourable effects on sleep and digestion it is almost equally certain that these effects had largely disappeared by the end of the first week after the change. This evidence in support of less frequent shift changes was, however, neutralized to some extent by the week-end break when most workers reverted to normal habits of life. Further, the results obtained in the present inquiry, like those recorded by Vernon in the 1914–18 war, show that absence tended to increase in successive weeks on the night shift. Vernon (1918) also found that, when shifts were changed every fortnight, output on the night shift was less in the second week than in the first week. It would appear, therefore, that the physiological evidence in favour of less frequent shift changes is not supported by the records of absence and output. Neither does it accord with the general dislike of night work and its interference with social and family life. On the whole, the balance of available evidence suggests that, so long as night work is necessary, a fortnightly change of shifts would be the most effective compromise from the standpoint of health, efficiency, and personal satisfaction, but further investigation is necessary before definite conclusions can be established. The only real solution to the problem is, of course, the abolition of night work except in times of emergency and in certain continuous processes. There is not the least doubt that night work is unpopular and, in the long run, is detrimental to health, efficiency, and the enjoyment of life. In every group of workers, some break down in health after a few weeks, months, or years of night work. These are the obvious casualties but it is reasonable to suppose that almost all workers are adversely affected in some degree and brought nearer to the point when the effects can no longer be ignored.

Summary

Output.—Output on night work was slightly less than on day work and this difference was equally noticeable whether shifts were changed weekly, fortnightly, or monthly.

When shifts were changed fortnightly, output on the day shift was higher in the second week than in the first week. An increase in output in successive

weeks of the day shift was also noticeable when shifts were changed every month.

Although most of the men produced more on the day shift than on the night shift, some (about one-third) worked just as well or even better on the night shift.

Absence.—Although factory records are likely to show more absence on day work than on night work, mainly because of the employment on day work of men who are unfit for night work, there was little difference when comparisons were limited to the same men employed on day and night work in alternate periods.

When shifts were changed every two weeks absence on the night shift was higher in the second week than in the first week of the fortnight. On the day shift the opposite tendency was noticeable.

When shifts were changed every four weeks, the amount of absence in successive weeks also tended to increase on the night shift and to decrease on the day shift.

Attitudes.—Almost all the men preferred day work to night work mainly because it was believed to be better for health, output, and social life. The attitude to the frequency of shift changes was determined more by custom and habit than by the intrinsic merits or defects of weekly, fortnightly, and monthly changes of shifts.

Feelings of fatigue, both during and after work, were more widespread and severe on night work than on day work.

Most of the men said that night work caused a loss of appetite and upset digestion. After changing to night work 27% of the men took from one to three days to settle down to the new meal times, 12% took from four to six days, and 23% needed longer. A fairly large proportion (43%) took patent medicines, usually every day or several times a week.

Many night workers (42%) claimed that they were unable to get enough sound sleep during the day. Almost 37% had less than six hours of sleep and 75% had less than eight hours. On the whole, changes in sleeping times seemed to be less disturbing than changes in meal times.

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LEGISLATION AND LITIGATION

COMMENTS ON THE DEVELOPMENT OF INDUSTRIAL LAW

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It is usually suggested that the three great sources of our law are case law (in the sense of the "common" law), equity, and legislation, and that, historically, this is the order of their coming; first the common law, then equity, then parliamentary legislation. But, though it contains truth, such a view is too simple. It is too commonly imagined that the common law relates to something in the past which has yielded place, under the strain of modern conditions, to a much more rapid and efficient system of law making by parliament and executive. In fact, on the one hand, the common law is still with us—still creatively with us—and on the other, legislation has had a decisive influence in certain fields for seven hundred to eight hundred years. Indeed, as has been pointed out by Ilbert (1901) [1]:

> "There have been three great constructive periods of English Legislation—the Edwardian period, which laid the foundations of our political and judicial institutions; the Tudor period, which came after the close of feudalism and at the beginning of the 'new monarchy', which strove to give effect to the ideas of the Renascence and Reformation, which dealt vigorously and unsparingly with the mediaeval church, and undertook the responsibility of discharging, through the secular state, functions which had previously been considered to belong to the domain of the Church; and, lastly, the period which followed the Reform Act of 1832, and which, in some senses may be said to be continuing to-day."

And yet during these periods the common law was not uncreative either. In fact, from the lawyers' point of view there are two kinds of law, in one of which parliament has made itself pre-eminent and in the other the hold of the courts has been almost unchallenged. What is remarkable is not perhaps that the judge in his function of law maker should continue, but that his elasticity and adaptability should be so marked.

One of the first effects of the industrial revolution was to create a spate of legislation, though much of it was what we should now call local legislation: Acts, which empowered the building of bridges, canals, railways. Institutionally, there was no break in the barrenness which had persisted since the great reforms of the Tudors.[2] But after 1832 the picture changed.

> "Take up a volume", says Ilbert, "of the eighteenth century Statutes and compare it with a volume of the Victorian period, and you will find yourself in a new world. In the eighteenth century there was no local Government Board, no Board of Education, no Board of Agriculture. . . . Nor were there county councils, district councils, parish councils. The functions of the central and local authorities were comparatively few and simple", and he goes on to add, "The net result of the legislative activity which has characterised . . . the period since 1832, has been the building up piecemeal of an administrative machine of great complexity, which stands in as constant need of repair, renewal, reconstruction and adaptation to new requirements as the plant of a modern factory. The legislation required for this purpose is enough, and more than enough, to absorb the whole legislative time of the House of Commons, and the problem of finding the requisite time for this class of legislation increases in difficulty every year." [3]

Indeed Parliament in this third period of legislation has come full circle and we are in substance back to the practice of Parliament in the time of the first Edwards, in which the King by his ministers made the law. Parliament's absorption in activity of this kind was a matter of anxiety to common lawyers even before the turn of the century. Writing in 1895 Pollock thought that "the besetting danger of modern law is the tendency of complex fact and minute legislation to leave no room for natural growth, and to choke out the life of principles under a weight of dead matter which posterity might think no better than a rubbish heap." [4]

1. Ilbert, C. (1901). *Legislative Methods and Forms*, p. 211. Clarendon Press, Oxford.
2. Ibid.
3. Ilbert, op. cit., pp. 211, 212, 213.
4. Pollock, F. (1904). *Expansion of the Common Law*, p. 8. Stevens, London.

Time has shown that this is too conservative a view both of the worth of much parliamentary legislation and of the growth of what has so often been called "lawyers' law", the type of law, which speaking generally, arises from the activities of a judge applied to problems raised by litigation. For Parliament is still relatively little concerned with the rules of contract, tort, property, family relations, succession and inheritance, and the like. And within these fields the anvil of litigation is still extremely potent. Speaking generally, legislation is more usually a mirror of the evils of a society, of the defects from which it suffers, than the pattern of a new society, and the value of Parliament's activities is not so much in the field of creative law as in administrative regulation. From the historical point of view legislation is rather like the written Utopia, not necessarily a valuable guide to the future but a manifestation of the society which gave it birth. Somebody looking at the Bankruptcy Acts in series once remarked that they revealed the problem before Parliament as that of drawing a net narrow enough to catch the rogue but wide enough to let the unfortunate escape. The Factory Acts reveal the same process.

The first of these early efforts at factory legislation was hesitating and tentative in the extreme, even the name, "An Act for the Health and Morals of Apprentices and Others" indicating Parliament's reluctance to wander into the new fields. The Act was aimed at the old parish apprentice system and contained some humane features but was largely ineffective, for it was aimed at a system which had passed its zenith. The habit of employing parish children was yielding to the employment of "free children", whose own parents often were a vested interest against reform, or about whom, since they were employed under a so-called voluntary contract, it was not nearly so easy to rouse public opinion. Other Acts were passed between then and 1833, Acts containing important principles but breaking down almost always on the question of enforcement. It was indeed not until an adequate system of factory inspection was provided that parliamentary legislation became in any way influential, for it was through the inspectors that knowledge became available; through them that the fund of experience upon which legislators might draw became almost inexhaustible, their records and reports yielding a rich dividend in formulating the problems which Parliament must face. Parliament thus began to replace the general obligation by obligations laid down with some care, and the process went so far that between 1901 and 1937 Acts were chiefly aimed at filling gaps or meeting changes imposed by technical or scientific advance. Then in 1937 came an Act which though it has novel provisions is primarily aimed at consolidating the existing law, at excising anomalies, and eliminating obsolete distinctions.

Thus over a century and a quarter Parliament has built up a comprehensive code of minimal requirements in the fields of health, safety, and welfare. But despite all this parliamentary labour there were fearful gaps, and black indeed would have been the plight of the injured worker if the courts had not, by means of adjudications upon cases before them, built supplementary codes of obligation in his favour. For though the Factory Acts showed great concern for the conditions under which a man worked they showed little for the man who was harmed by his employer's failure to obey the law. The employer might be fined for his breach of duty, but the injured workman came under parliamentary consideration at one point only, namely, in the provision that where a workman is killed or injured because of a breach of the Act, the occupier will, without prejudice to any other penalty, be liable to a fine not exceeding £100 which may be applied in whole or part for the benefit of the injured person or his family.[5] And the poverty of this remedy is the more striking when it is recalled that almost a century elapsed between the passing of the first Factory Act (1802) and the first Workmens Compensation Act (1897).

Now, by any standards, such provision for loss of life or injury is quite inadequate, and the courts recognized this. An action for negligence would lie, but that too, from the point of view of an injured workman was largely a delusory remedy, for when industry assumed a hierarchical structure to fasten personal negligence on an employer was extremely difficult; to fasten it on anyone *less* than an employer, meaningless. The courts moved along two lines. In 1854 one Couch, a seaman, suffered illness through the absence on board ship of medicines which the shipowner was required by Statute to provide. It was held that he might recover, although the Act in question, like the later factory acts, merely provided a penalty payable to the State and did not expressly give a right of civil action.[6] The court, faced with an Act of Parliament passed for the benefit of a particular class of people, containing a penalty but no right of action, will ask itself whether this penalty is intended to be exhaustive: will ask whether it was Parliament's intention to exclude an action upon the part of a person injured by the breach. Thus

5. Factories Act 1937. Sec. 133.
6. Couch v. Steel (1654). *Ellis and Blackburn*, vol. 3, p. 402.

the court, on the basis of litigation brought by aggrieved persons, has evolved a civil action for a breach of statutory duty which has been applied to a wide range of Acts, notably to the Factories, the Mines, and the Shops Acts, and thus the courts have done for the injured workmen what Parliament originally did not seem to think it was its duty to do. Today, one cannot take up a volume of law reports without reading cases in which the courts have come to the aid of the injured workman and his family. The civil action for breach of statute has become a part of the legal background of the nation.

The second development was, in its origin, even more interesting, because it is not clear that the judge concerned really foresaw the consequences which were later to arise from certain of his words in the judgment he gave. In 1837 Lord Abinger decided the case of Priestley v. Fowler,[7] the first case in English law, as far as one can see, in which an injured workman had the temerity to sue his employer. Priestley was employed by a butcher, and in the course of his employment, had to ride on the butcher's cart. This was overloaded, a wheel gave way, and Priestley was injured. Priestley did not allege in the averment that his master knew of any defect in the vehicle, or that it was overloaded, but in evidence made it clear that the master did know this. It was held that the employer was not liable. His Lordship was clearly disturbed, and lest personal comments be deemed biased, let Lord Atkin, discussing the case a century later, be quoted :

> " Lord Abinger felt that he had to decide the case on general principles, and was at liberty to look at the consequences one way or the other. Surveying them he was alarmed, for he found that if the master was liable, he would be liable for the negligence of all his ' inferior agents ', e.g. to the footman for the negligence of his coachman ; . . . to a domestic servant for the negligence of a chambermaid, the upholsterer, the cook, the butcher and the builder. A more remarkable medley of so called agents it is difficult to conceive. Faced with the absurdity of these consequences, the court concluded that the master is not bound to take more care of the servant than he may reasonably be expected to do for himself " [8].

Lord Wright went further when he said that " these instances seem to show personal apprehensions rather than any principle " [9].

Historically, the importance of Priestley v. Fowler was twofold. It originated the doctrine of " common employment ", an unhappy doctrine which laid down that where a servant was injured as the consequence of the act of another servant upon whose safety he was dependent, this was to be accounted one of the risks of the employment for which the employer would not be responsible. It was a doctrine against which the courts learned to protest and which they refined and distinguished with as much ingenuity as they were capable of, but by which in essence they felt bound. Yet, apart from a limited effort in 1880, it was not until 1948 that Parliament felt sufficiently moved to end the sorry business.

But Priestley v. Fowler had another series of consequences which have been less commented upon than the doctrine of common employment, for the judgment contains what was at that time the novel suggestion that the master owed a duty, as yet vague and undefined, to take reasonable care of the safety of his servant.

> In truth ", Lord Abinger said, " the mere relation of master and servant can never imply an obligation on the part of the master to take more care of the servant than he may reasonably be expected to do for himself. He is, no doubt, bound to provide for the safety of his servant in the course of his employment, to the best of his judgement, information and belief."

Those words are, in fact, the origin of a code of rights and liabilities which have filled the legislative gaps to which reference has been made. A workman, it is said, must accept the hazards of working alongside his fellow workmen, but this is soon glossed by the courts and it is held that an employer will be liable to his workman for hazards arising from (*a*) his failure to select servants of competent care and skill, and (*b*) his failure to safeguard his servant from " unreasonable risks ".

The law begins to develop with some rapidity, in Scotland more so than in England, and it comes to be established that a master owes a personal duty of care towards his servant, and that this duty operates in respect of the place of work, the plant, and the machinery involved, and where the master delegates these duties to another, he will none the less remain responsible to that other. The story of these developments is fascinating in the extreme, but cannot be discussed here. It is sufficient to recall that faced with a situation in which the hazards of employment were increasing with great rapidity and with a Parliament which remained, on the whole, mute as to the rights of the individual workman, the courts built up a threefold obligation for the employer ; namely, the obligation to provide a competent staff ; the obligation to provide adequate equipment and material ; and the obligation to fuse the two into what the law calls " a

7. *Meeson and Welsby*, vol. 3, p. 1.
8. Quotation from the judgment of Lord Atkin in the case of Radcliffe and Ribble Motor Services Ltd. (1939). Appeal Cases vol. 215, p. 225.
9. Ibid. at p. 239.

safe system of working", the latter proving a remarkably elastic and resilient concept by which the courts could secure justice for the injured workman. How can it be contended in the face of this that the courts have ceased to function except in the lesser role of interpreting legislation? How can it be suggested that the only potent source of law is Parliament? For of course in suggesting that the courts still act in the role of creative law making, I am suggesting what many would regard as heresy.

Yet it is probable that we are to-day witnessing in the same field of litigation a new development which is likely to be as fruitful as was the development of employers' liability last century. The courts are today evolving, it may be suggested, a code of employees' liability of the utmost significance. For in one respect the law, whether the creature of Parliament or of the courts, was defective. A workman who was himself negligent and was injured might find that he could not succeed or could succeed only partially in recovering damages. Indeed it was not until 1940 [10] that the House of Lords finally decided that contributory negligence was a defence to an action for breach of statutory duty, and even then it was clear that the courts, in construing what amounted to contributory negligence, would lean in favour of the workman. A workman, it is true, would not recover if he did not take ordinary care for his own safety but the degree of care would vary with the circumstances, and a different degree of care might be expected from a workman in a factory than that which might be expected from an ordinary man not exposed to the noise, strain, and manifold risks of factory or mine. Lord Wright went further. The courts, he said, have accepted contributory negligence as a defence "but the policy of statutory protection will be nullified if a workman were held debarred from recovering because he was guilty of some carelessness or inattention to his own safety".[11] He made it clear that if he had been free to do so, he would have made a workman liable only where his conduct was so grave and so directly caused the accident as to shift responsibility from his employer to himself.

The courts were clearly uneasy, at this stage, about the law; they were doubtless worried about the disparity of the sanction and the act of carelessness (the sanction being the refusal of civil remedy); they were unwilling to feel that contributory negligence should be a complete defence but felt themselves powerless. Statute came to their aid in 1945 and while the defence of contributory negligence is still available, under the Law Reform (Contributory Negligence) Act 1945, damages are apportionable between the parties according to their degree of culpability.

All this has enabled the courts, secure in the knowledge that the merely careless or stupid workman and his family are not entirely bereft of compensation, to look at the situation which arises when the employer is compelled by Statute to provide safety devices and facilities which the workman fails to use. In the 1937 Factories Act, Section 119, it is provided that a workman must not wilfully do anything likely to endanger himself and others, nor wilfully interfere with or misuse anything provided under the Act for securing health, welfare, and safety and must use any such means or appliances provided. The provision is not strong; it is difficult to see how it could be enforced, except negatively, either by fining the offending workman for his breach of the Act and reducing or denying damages to him if he injured himself. But what of the situation where his action injures his fellows or damages his employer's property? In principle there is no reason why he should not be sued civilly, but there is little to be gained in suing a man of straw. So again, the employer would have to bear the brunt.

But there is some evidence that the courts are looking at these questions anew and are slowly building a code of employees' liability. The statutory provision was first looked at in Wraith & Flexile Metal Co. Ltd.[12] A girl worker, in an effort to retrieve a cylinder which had fallen, had crawled under a drying oven and been injured. She sued her employers, who pleaded contributory negligence and her failure to use a safety device provided. For they had given instructions that employees were not to go under the ovens and had provided a broom with which to retrieve any fallen objects. This argument the courts would not accept: the accident, the court believed, arose from a failure securely to fence, and the object of the Factories Act was declared to be the protection of workers against their own folly. At this stage then, it was clear that an employer who was himself in breach could not set up the breach of his employee and might not excuse the absence of a superior safety device by showing that he had employed an inferior one. That was in 1943, but by 1952 it is possible to detect a stiffening in the attitude of the courts. In Norris v. Syndi Manufacturing

10. Caswell v. Powell Duffryn, Associated Collieries Ltd. (1940), Appeal Cases, p. 152.
11. *Ibid.* at p. 179.
12. (1943). King's Bench Division, p. 24.

Co. Ltd.,[13] a tool setter, while making adjustments, removed from a power press the guard which had been fitted by the defendants and failed to replace it when testing the press in motion. It was held that he could not recover. The defendants in fitting a guard had provided a device for the plaintiff's safety which he was under an absolute statutory duty to use. He was therefore in breach of Section 119 of the Factories Act and damages awarded to him by the trial court must be reduced by one-fifth. There was some evidence that his employers had acquiesced in his working without a guard but this did not unmake the man's own offence. He had a duty independent of the employers for a breach of which he must be responsible in damages.

Two other cases merit discussion. I choose them only because they show developments in principle. The first is of considerable interest, for in Paris v. Stepney Borough Council [14] the plaintiff, a garage hand who had already lost the sight of one eye, was blinded by a piece of metal which flew when he was attempting to knock a nut from a bolt. Mr. Justice Lynskey in the court of first instance held that the employers were negligent, but the Court of Appeal disagreed. The House of Lords found for the plaintiff, reinstating Mr. Justice Lynskey's decision, though varying the reasons. Mr. Justice Lynskey had said that since the employers were aware of the man's partial blindness, they should have provided goggles. The Court of Appeal, and particularly Lord Justice Asquith, felt that a distinction should be made between risks and consequences. The risks of accident to a partially blind man were not necessarily greater than those to a sighted man, though the consequences of accident were greater, and it was unfair to visit upon the employer those additional consequences. Certainly were it not for the Disabled Persons Act employers, after Paris's case, would have been reluctant to employ disabled persons, for they were increasing their own obligations when they did so.

In Paris's case the employer knew of the defect. What would be the position where the employer had no such knowledge? We had not long to await the answer. Last year the courts heard the case of a workman who was injured by falling from a platform twenty feet above ground level, which, contrary to the building regulations, was not 34 inches wide and did not contain the proper guard and toe rails. But the workman suffered from epilepsy and had been told by his doctors not to work above ground level. It was held that responsibility was equal, and the damages reducable by one half.[15] The case is extremely important. The seller of goods and services has never been required by the common law to enumerate their defects. Who amongst us would have got a job otherwise? The duty of disclosure has not existed. It does now, and a new obligation is firmly placed on the shoulders of the workman. In other words, whereas formerly the tendency of the courts was to emphasize the responsibility of the employer, there is now some evidence of a changed emphasis, and the obligations of the workman are the subject of much consideration.

Why, then, have the courts been so effective in a period of much legislative activity, first in developing the law and secondly in the creation of remedies?

Firstly, it may be argued, because of the changed legislative background. Law makers, whether parliamentary or judicial, cannot move far ahead of the *zeitgeist*, the notion of public policy, of national expediency, of the sovereign people, or what you will. As Mr. Justice Holmes said in Southern Pacific Co. v. Jensen,[16] "The Common Law is not a brooding omnipresence in the sky, but the articulate voice of some sovereign or quasi sovereign". And the last dozen years have seen important legislative changes: the abolition of the doctrine of common employment, the Law Reform (Contributory Negligence) Act 1945, the creation of a comprehensive system of insurance, domestic and industrial, and the abolition of the system by which the injured workman was put to his election between workmen's compensation and actions at common law.[17] The first two of these changes—though made by Parliament—owed much to the criticism of the courts. But there has been a century of legislative change in a deeper sense.

> "In substance", wrote Oliver Wendell Holmes, "the growth of the law is legislative. And this in a deeper sense than that what the courts declare to have always been the law is in fact new. It is legislative in its ground. The very considerations which judges most rarely mention, and always with an apology, are the secret root from which the law draws all the juices of life. I mean, of course, considerations of what is expedient for the community concerned. Every important principle which is developed by litigation is in fact, and at bottom, the result of more or less definitely understood views of public policy." [18]

13. (1952). All England Law Reports, vol. I, p. 935.
14. (1951). Appeal Cases, p. 367.
15. Cork v. Kirby Maclean Ltd. (1952). All England Law Reports, vol. 2, p. 402.
16. Oliver Wendell Holmes (1881). *The Common Law*, p. 35.
17. The problem of alternative remedies has been shelved, not solved. Because the employer is a contributor to the National Insurance Scheme, The Law Reform (Personal Injuries) Act, 1948, Sec. 2 (1) provides that in certain cases damages at common law are to be reduced by one half the estimated value of the insurance benefits to be received by the workman.
18. *The Common Law* (1881), p. 35. Little, Brown, & Co. Boston.

In Holmes' sense also, then, there have been legislative changes, though it is not easy to reconcile their consequences. It may have been expedient originally that employers should be protected; that gradually it should be the employee who became the centre of interest. But how to explain a stiffening of the courts' attitude against the workman contemporaneously with the establishment of the welfare state? May it not be that the welfare state will be able to deal more effectively with the workman who fails to use the facilities provided than was possible in a capitalist society? There are indications that it may be so.

Secondly, looking at the last century of law making, admittedly in only one, though as I believe, representative field, one cannot escape the feeling that the machinery of the courts has certain advantages over Parliament where individual rights are concerned, which is perhaps to do nothing more than call attention to the old distinction that laws are general and cases particular. Parliamentary conservatism and inertia are fearsome things and legal inertia and conservatism not less so, but the history of the last century does suggest that it is still possible for men of courage and originality to influence affairs with great effect from the bench. For this also must be said; whatever may be true of its origins, the survival of the common law as a law-making instrument depends as much on a wise departure from accepted tradition as upon insistence upon it. Its development, and hence its usefulness, derive not so much from a bench of judges swearing fealty to the common law and resisting any departure therefrom, as upon one or two judges, progressively minded, thinking always of the ends law must serve and how best it may serve them in our time. One judge of this temper of mind has recently reminded us of this. He was dealing with counsel who had told him that he could not do this and that because there was a lack of authority on the matter.

> "The argument about the novelty of the action does not appeal to me. It has been put forward in all the great cases which have been milestones of progress in our law, and it has always, or nearly always, been rejected. If you read the great cases of Ashby v. White, Pasley v. Freeman, and Donoghue v. Stevenson, you will find that in each of them the judges were divided in opinion. On the one side there were the timorous souls who were fearful of allowing a new cause of action. On the other side there were the bold spirits who were ready to allow it if justice so required. It was fortunate for the Common Law that the progressive view prevailed. Whenever this argument of novelty is put forward, I call to mind the emphatic answer given by Pratt, C. J., nearly two hundred years ago in Chapman v. Pickersgill, when he said: 'I never wish to hear this objection again; this action is for a tort: torts are infinitely various, not limited or confined, for there is nothing in nature but may not be an instrument of mischief.' The same answer was given by Lord MacMillan in Donoghue v. Stevenson, when he said: 'The criterion of judgment must adjust and adapt itself to the changing circumstances of life. The categories of negligence are never closed.' It needs only a little imagination to see how much the Common Law would have suffered if those decisions had gone the other way." [19]

And thirdly, this review does suggest that it is in the development of new causes of action and in the adaptation of old causes to new situations that the courts have had a considerable success. Parliament has built up codes of rights and obligations, so too have the courts, but in this they have followed the traditional common law method of concentrating on remedies. That apparent illogicality—where there is a remedy there is a right—has been a continuing source of strength to the common law. It is so often meaningless to talk of rights if there is not the means to enforce them. The courts throughout the first century of industrial legislation have in fact been not less progressive than Parliament in matters concerning the welfare of the injured workman, and in the creation and enforcement of remedies.

19. From the judgment of Lord Justice Denning in the case of Candler v. Crane, Christmas & Co. (1951). King's Bench Division, vol. 2, p. 178.

Brit. J. industr. Med., 1953, **10**, 179.

FROM FACTORY INSPECTION TO ADULT HEALTH SERVICE

A REVIEW OF GOVERNMENTAL ADMINISTRATION OF OCCUPATIONAL HEALTH

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In western Europe, the view seems to be widely held that the protection of the health of workers, by definition and by practical necessity, must be a legal responsibility of ministries or departments of labour. There are good historical reasons for this viewpoint, and considerable practical experience to back it up. In today's world, however, where newly industrializing countries are looking to the west for advice, it is worth examining the assumptions of this principle. Certainly, one does not want to export ideas about social organization and governmental administration which would not apply well in other cultures or, indeed, may not even be properly meeting the current needs of the older industrialized nations themselves.

Historical Development

The rise of factory inspection in Great Britain in the early nineteenth century, and later on the European continent, was a reaction to the squalor of contemporary industrial production methods. It reflected the growing humanitarian conscience of the day and was the response of government to the demands of working people for a decent life. Naturally, the primary focus was on the protection of the worker—and more especially the woman and child worker—against the harmful effects of the work itself. Occupational diseases, like lead poisoning and " miner's asthma ", had been known for some time, and some effort could reasonably be made toward their prevention. The general environment of the factory could be assured, at least, to meet minimum standards of hygiene (Teleky, 1948).

Here and there, benevolent employers made an effort to provide good working conditions for their workers, independently of legal inducement. These employers, in fact, helped to inspire the enactment of welfare laws. On a wide national scale, however, the police powers of the state had to be invoked, and inspection services had to be developed to compel general compliance with minimum standards. The physical environment of the factory was, of course, only one aspect of the labourer's welfare, of which hours of work, periods of rest, and the status of children and women were others. Departments or divisions of labour welfare were the obvious governmental instrument for exercising this authority to inspect and enforce compliance.

Toward the latter part of the nineteenth century and the early twentieth a new conception entered industrial life, namely, the responsibility of employers for the social consequences of industrial injuries. Behind the first industrial injuries or workmen's compensation acts was a long story of social and legal battle. The eventual effect of the new laws, however, first in Europe and later in the United States, was to induce employers to protect their workers by guarding dangerous machinery, installing safety devices, and introducing various measures to reduce accidents.

The first full-time factory inspectors were appointed under the British Factory Act of 1833, and the pattern spread rapidly. In 1898 the first Medical Inspector of Factories was appointed in recognition of the need for understanding the human reaction to toxic substances, as well as the purely environmental aspects of industrial hygiene. In the United States of America, a few states, in the 1880s, appointed factory inspectors to enforce labour codes but all the states did not

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have factory inspectors until about 1920; and medical guidance was rarely incorporated in the inspectorate. Whether or not medically guided, factory inspection was obviously oriented toward the removal of specific hazards of the industrial environment which might contribute to occupational diseases or industrial accidents. On the whole, the inspection programmes in Europe were undoubtedly effective; the incidence of occupational diseases and industrial accidents—relative to the increasing numbers of persons engaged in industry—was reduced.

In the early twentieth century, under the influence of factory inspection and workmen's compensation laws, employers came to recognize that productivity could be increased and the workers kept better satisfied by providing some direct medical services at the place of work. Physicians were occasionally appointed for regular service in the larger plants and mines. Such appointments were sometimes related to the need for some general medical care in isolated areas, but more often to the desire of employers to reduce compensation insurance costs by providing prompt first aid and treatment of injuries. Such industrial physicians could also perform medical examinations on job-seekers so as to prevent employment of persons physically unsuitable for the work.

The conception of an industrial health service gradually widened to include not only treatment of injuries and pre-employment medical examination, but also general preventive health services, medical care for minor illnesses occurring on the job, counselling of the worker on all health problems, and supervision of the work environment. The aim came to be adjustment of the man to his job and the job to the man. This approach developed in the larger plants which had financial resources for the service, and was not made a legal requirement. Laws came to be passed requiring the availability in plants of minimal first-aid staff and equipment, but the engagement of full-time medical staffs, specially trained for the purpose, was a matter for private initiative. While this scale of industrial health service, therefore, has come to cover only a small minority of workers—even in the well developed economies of western Europe and North America—the theory behind it has taken a firm root in social thinking. In recent years, as we shall see, it has had an impact on health legislation.

This broader conception of health protection of workers is of special importance in relation to the place of supervisory authorities for the workers' health in the structure of government. For, while the theory and practice of industrial health service has been expanding, a similar evolution has taken place in government. The role of public bodies, national and local, in the protection of the health of the general population has gradually broadened. The trend has applied to both preventive and curative medicine. Many governmental agencies are involved in this process, but the most important are the ministries or departments of health in which professional skills in medical-social administration have become increasingly gathered.

It is not surprising, therefore, that as the scope of interest in occupational health has broadened from the narrow sphere of occupational disease and accident prevention to the broad sphere of total health service, public health agencies have been brought closer to the factories and mines. The advantage or disadvantage of this relationship will be considered below, but first it may be helpful to review the current methods of administration of occupational health services in government throughout the world. It may surprise some readers to find that the western European patterns are by no means universal.

In this review, it is helpful to keep in mind a distinction between the supervisory responsibilities of government, and the direct responsibility for clinical preventive or curative services at the place of work. Our focus here is on the former, and this has importance insofar as it may affect the latter. Just as we have seen the influence of private industrial practices on legislation historically, it is obvious that the legislation and methods of governmental administration will shape the content of health services rendered within the factory, mine or other place of work.

Current Governmental Practices in Western Europe

The basic patterns of factory inspection developing in the early nineteenth century still prevail in the countries of western Europe. This is not to imply that governmental activity has remained static. Far from it; the scope of the factory inspectors has steadily widened to include all aspects of the working conditions, but the principal objective remains the enforcement of standards designed to prevent occupational diseases and industrial accidents. Beyond this, the medical inspectors of factories are responsible for supervising enforcement of laws regarding medical examinations of certain groups of workers, maintenance of first-aid boxes or factory dispensaries, and other measures designed to protect workers against specific hazards.

In all countries of western Europe special efforts have been made to develop preventive and, to some extent, curative medical services within factories

even without legislative inducement. As a general rule, these health services have been developed by the larger industries quite independently of the requirements of the factory inspection laws. Occasionally, medical inspectors of factories have participated in the promotion of such services, but usually in a voluntary capacity, as informed professional leaders.

The situation in Norway illustrates the general pattern, although in no two countries are practices exactly alike. The Norwegian Ministry of Labour contains a Directorate of Factory Inspection, first organized in 1892 (Natvig, 1952). It has a staff of seven labour inspectors covering the country on a district basis, three inspectors of special problems, and three medical inspectors. They make periodic inspections of plants to enforce legislation designed to prevent occupational diseases and accidents, the principal current law being the Workers Protection Act of 1936, with amendments. Pre-employment and periodic medical examinations are required for young workers of 15 to 18 years of age, and for workers exposed to silica and to radioactivity. In each of 750 communities there is a local labour inspection committee to help enforce the law. An Institute of Occupational Health is maintained by the Ministry of Labour in Oslo to assist in the diagnosis of occupational disease and to perform relevant laboratory tests (W.H.O., 1952).

Apart from the provisions mentioned, governmental authority is not concerned with the organization of general health services in plants, but a voluntary body has been established for this purpose. This is the Industrial Medical Service Council representing the Norwegian Federation of Labour, the Employers' Association, and the Medical Association. This body sets standards for comprehensive in-plant health services which would include pre-placement and periodic medical examinations of *all* workers, constant supervision of plant hygiene, first aid and treatment of minor ailments occurring on the job, and referral of workers to personal physicians for diagnosis and treatment of general illness (Bruusgaard, 1952a). There is no compulsion in this programme, and only a small minority of Norwegian workers is covered, but the services are spreading. Cooperation is encouraged with the local public health services in such practices as tuberculosis case finding and reporting, but there is no official connexion with the country's public health framework, national or local.

The other Scandinavian countries have a somewhat similar arrangement. In Sweden, Denmark, and Finland the factory inspectorate is in the Ministry of Social Affairs (rather than a separate Ministry of Labour), but the functions are essentially the same. In Finland there is an Industrial Medical Association devoted to the voluntary promotion of in-plant medical services, very much as in Norway. Research, training, and specialized services for the detection and control of occupational diseases are given by an independent, but government-supported, Institute of Occupational Health at Helsinki (Noro, 1951). In Sweden a somewhat similar research institute for occupational health is located within the National Institute of Public Health, achieving in this way some coordination with other health research activities (Forssman, 1952).

Practices in Germany reflect the basic approach in central Europe. Being one of the oldest and largest industrialized nations, with a strong tradition of governmental control, Germany has a deeply rooted system of factory inspection. In each German state there is a department of labour which contains a factory inspectorate, divided into a medical branch and an engineering branch. The engineering branch enforces regulations on environmental standards in the factories. The medical branch is staffed by "state industrial physicians" whose main duties are to determine if illness is of occupational origin, and, therefore, entitled to workmen's compensation, and the degree of disability, to act as medical consultant on the treatment of occupational disease cases, to help enforce regulations on the prevention of occupational diseases, and to advise the engineering branch on environmental controls. Tabershaw (1951) has observed that "none of the state industrial physicians have any concept that their functions embrace interest in non-occupational disease, in the total health of the worker or in furthering general public health". Health services developed in some of the larger plants are devoted to giving medical examinations to certain workers exposed to special risks and first aid for occupational injuries and other minor ailments. There is little tendency to go beyond the minimum requirements of the law.

The detailed specifications of the classical factory inspection systems of each European country need not be reviewed. A complicated legal structure has grown up over the years, establishing minimum precautions which must be taken by industry to prevent accidents and certain specified occupational diseases. There are also requirements for first-aid services and supplies which must be available in the plants, for general toilet and washing facilities, for the use of safety devices, and for basic standards of space, lighting, ventilation, etc. The enforcement of these regulations is the duty of the factory

inspectorate. With minor exceptions, there is no connexion between the factory inspectorate and the general public health programme of the region.

The relatively narrow scope of the factory inspection approach has been realized in Europe for some years, especially since occupational accidents and diseases have been reduced. It took the social upheaval of the second world war, however, to cause a major extension in its scope particularly in the French-speaking countries where the upheavals of war and foreign occupation were so great. This is seen best perhaps in the introduction in Belgium and France of the requirement of a general medical examination of all workers before employment. Largely through the practical demonstrations of health programmes in big industrial undertakings, the concept grew that it was to the common benefit of the industry and the worker not only to prevent accidents and industrial intoxications, but also to assure that a worker was physically and mentally suited to a particular job, a principle commonly applied to young workers and to women for some years.

The Belgian law of 1945 requires that each undertaking is responsible for a medical examination of every worker before employment at the expense of the employer. The examinations are performed by any practitioner chosen by the worker, according to a prescribed form. A radiograph of the chest must be included, and may be performed by the National Institute for the Control of Tuberculosis (a semi-autonomous organization working closely with the Ministry of Public Health and Families) or by a qualified private physician. The physicians of the factory inspectorate limit themselves to seeing that the examinations are made. The declared purpose of the procedure is not only to assure suitable job placement but also " to inform workers concerning any disorder or deficiency from which they may be suffering and to indicate institutions which can facilitate treatment " (W.H.O., 1951).

This wider protection of the worker's health under the ministries of labour is seen more strikingly in France. After a conventional factory medical inspection system which had operated since 1915, France enacted in October, 1946, the most far-reaching legislation of any western European country. For the first time in a western European country, the provision of a systematic medical service in every factory, regardless of size, was made compulsory (Bousser and Gillon, 1952). This service must provide not merely pre-employment medical examinations of all workers but annual re-examinations, and more frequent re-examinations of young persons and workers exposed to special hazards. Annual chest radiographs of all workers are required. Emphasis is placed on proper job placement of the individual according to his particular capabilities, rather than exclusion of the unfit. First aid and diagnosis of any illness is provided in the plant, but for medical care the worker is referred to a personal physician. These services are to be rendered by part-time or full-time physicians engaged by the employer. The law specifies one medical hour per month for about every 15 workers (less for white-collar workers and more for workers under special risk), so that a full-time industrial physician is required for about every 2,250 workers.

This programme is supervised by the Medical Inspectorate of Labour and Manpower of the French Ministry of Labour and Social Security. The 14 regional medical officers of this agency must approve of the medical arrangements made by all employers in their region, and it is their duty to help to organize the services required by the 1946 law. They promote the grouping of small plants which, together, can engage the full-time services of a physician. They also carry out the usual duties of medical inspectors of factories in other countries, such as examination of specific cases of occupational disease for compensation claims, evaluation of environmental hazards, and enforcement—with the general factory inspectors—of regulations. Up to the present time, the new industrial medical service is far from complete, but progress is rapid. By January, 1950, approximately 50% of the workers, covered by the legislation, were being provided with medical services through programmes in 2,411 companies and 522 inter-company groups. The inspection staff has been unable to keep up with the task of reviewing and approving these services. There is no connexion with the public health services except in special instances, such as the impressive coordinated programme at Nancy, or the arrangement at Toulouse for nurses from the public health staff to serve in a local factory.

In all European countries, the organization of preventive services in the plants is, of course, influenced by the laws providing financial compensation to workers for industrial injuries and diseases. Large insurance companies may even provide this protection, as they naturally have a financial interest in keeping the accident rate at a minimum. In Italy, for example, there is a National Organization for Accident Prevention which not only conducts general educational campaigns, but actually operates medical clinics in the large plants, providing first-aid and minor medical services (Canaperia, 1950). The compensation laws have had the salutary effect of inducing employers to prevent accidents or reduce

disability resulting from them. At the same time, however, they have tended to concentrate action so much on compensatable conditions that too little attention has been given to the larger health problems of the worker.

Discussion of industrial health services in Great Britain has been delayed because, in the current debates and self-examination of the problem in that country, there are reflected some of the fundamental organizational problems that may eventually be encountered by all countries. With the organization of the British National Health Service, bringing virtually all health care, curative and preventive, under government control, authorities were faced with questions of administrative efficiency and with the necessity to spend the available health funds with maximum effectiveness.

As in continental Europe, factory inspection under the Ministry of Labour and National Service is focused primarily on the prevention of occupational diseases and accidents. There are some 15 regional medical inspectors of factories who are experts in the investigation of occupational disease and related environmental hazards. Spread throughout the country are some 1,700 appointed factory doctors—almost all part-time general practitioners—whose duty is to make medical examinations of young workers and workers exposed to special risks, and to investigate cases of occupational disease which are notifiable. The appointed factory doctors are paid by employers on the basis of the number of examinations they make, but they are administratively responsible to the medical inspectors of factories. There are approximately 1,300 full-time and part-time industrial medical officers, employed by private and nationalized industries for general in-plant health services. They are assisted by about 4,000 industrial nurses of whom about 2,600 are State Registered. The in-plant health services as in other countries are principally in the larger plants, except for a few special cooperative projects, like the Slough Industrial Health Service near London (Dale Report, 1951).

With the pressure on medical man-power under the National Health Service, and with the complexities of comprehensive health administration, many questions have been raised about the soundness of this general system. In 1949 a Committee of Enquiry on Industrial Health Services was appointed by the Prime Minister, under the chairmanship of Mr. Justice Dale. This report (known as the Dale Report, 1951) concluded that industrial health services of a preventive nature were valuable, that they were not available under the National Health Service, and that present patterns should be continued substantially without change. Reaction to these conclusions from many quarters was cool—not because there was lack of appreciation of the positive value of a good industrial health service, but rather because there was widespread feeling of a need for some closer administrative coordination with the National Health Service. Debate on this question has been active. In a symposium held at the Royal Sanitary Institute Congress in 1952 several new approaches were suggested. That receiving most attention was made by I. G. Davies (Davies, Schilling, and Banks, 1952). He suggested that supervisory responsibility for industrial health services at the community level should be under the local medical officer of health, who would be aided in carrying out these duties by the appointed factory doctors. Technical advice and consultation on the complex problems of occupational diseases would remain the responsibility of the regional medical inspectors of factories. Thus, at the higher levels, the Ministry of Labour and National Service would retain its responsibilities, but at the community level—where health service has its direct impact on people—the Ministry of Health could exercise appropriate supervision and integration of industrial health service with the total health programme

The debate and the proposals in Great Britain have particular significance internationally, because they are the first, or at least the major, instance in western Europe in which the separation of the factory inspection system from the public health framework of a country has been challenged. This basic issue of relationships between labour and health ministries in the supervision of the worker's health is latent in almost all countries, and it has become sharper as the scope and dignity of public health organization has increased. In the rest of the world, outside of western Europe, the respective responsibilities of these two agencies of government are much more fluid, and consequently the pattern of administration of occupational health supervision is taking different shapes.

North America

As in many aspects of social welfare, the assumption of governmental responsibility for the worker's health came later in the United States than in Europe. Virtually all responsibilities for health and welfare belonged to the States, and supervision of the conditions in factories by an inspection system was not started until the end of the nineteenth century. New Jersey and Wisconsin were the pioneers in 1883. Factory inspection programmes in state departments of labour developed slowly in the early

twentieth century, modelled after the European practices, but in the American climate of *laissez-faire* liberalism with minimum government control, they were not very strong. The inspectors were rarely trained in engineering or chemistry or other appropriate fields. In only one state was medical guidance sought, in New York State, where in 1907 a single medical inspector of factories was appointed, but the idea did not spread.

There was obviously a gap to be filled in the development of a scientific programme of industrial hygiene which could tackle both the environmental and the medical aspects of occupational diseases. In 1914, the United States Public Health Service attempted to fill this gap by establishing the Office of Industrial Hygiene and Sanitation, primarily for research purposes. Similar research activities were undertaken in the Departments of Labour of New York and Ohio, but on the whole the State and local public health agencies were not strong enough to do this work. As in Europe, here and there private industry developed preventive and, more often, curative programmes, especially in isolated areas and in large plants. The first world war gave this practice an impetus in the interest of preserving effective man-power. The workmen's compensation laws, which were initiated only after 1911, had the same effect—in the interest of reducing insurance rates. Then came the depression in 1929, and in 1935 a new opportunity was presented to the nation's public health agencies with the passage of the Social Security Act (Klem, McKiever and Lear, 1950).

Under this law larger funds were made available for public health services than ever before through the device of federal grants-in-aid to the States. The Public Health Service administered these grants and, having now had 20 years of experience in industrial health research, it used them to help the States develop industrial hygiene units in the State departments of health. The idea grew rapidly, so that today every state public health agency, except four, and several large city health departments contain specialized staffs for promoting the health protection of workers.

The functions of these public health units in industrial hygiene are very different from those of factory inspectorates. They are not inspecting agencies engaged in the enforcement of laws. They are primarily advisory technical bodies, devoted to the promotion within their states of sound hygienic practices within industry. It is not that they lack enforcement powers, as is sometimes believed, for all public health agencies have general powers to require correction of hazards to health (Trasko, 1950). It is rather that, in the American culture, health authorities are convinced they can achieve better long-term results by a process of education, demonstration, and persuasion than by the enforcement of laws. While the effectiveness of these industrial hygiene units differs markedly among the States, they have developed a nation-wide network of consultant services which has helped to reduce the incidence of occupational diseases to an extremely low level.

These developments have a far greater significance, however, than the integration of industrial hygiene services in the American public health system. An opportunity has been provided for bringing to bear the broad field of preventive health services, embodied in the modern public health movement, upon the workers in industry. The need of industry and the community as a whole is a healthy worker, and not merely a worker free from occupational poisoning or injury. The importance of this has become increasingly recognized as studies of sickness absenteeism in the United States have shown that, on the average, only about 5 or 6% of sickness absenteeism can be traced directly to conditions arising from work (Newquist, 1938). The overwhelming bulk of illness relates to non-occupational causes. Its reduction, therefore, not to mention the achievement of health, calls for a generalized health programme, such as can be promoted by the community public health agency. This concept was stated clearly several years ago by Bloomfield (1938).

> " It would seem, therefore, that if we are to improve the general health status of the most important and numerous group in our population, it will be necessary to control not only unhealthful conditions in the working environment, but also to give consideration to such factors as proper living conditions, nutrition, elimination of strain and hurry, communicable diseases—in fact, a general adult health program for all workers. In order to promote a broad and effective industrial health program of this type, it will be necessary to integrate it closely with existing public health activities."

Under the wing of the public health agency, industrial health responsibilities of government in America are increasingly taking the form of an " adult health service ". The factory is being used as a channel through which general public health programmes are promoted, very much as the schools are a channel for protection of the general health of children. Services are rendered for workers in the control of tuberculosis and venereal disease, immunization against infectious diseases, nutrition, general health education, detection of chronic disorders, environmental sanitation, mental hygiene, dental care, maternal and child health, and medical rehabilitation. Beyond this, industry is encouraged

to develop systematic in-plant services (Roemer, 1948). Not that this ideal integration is achieved everywhere, but this is the direction for which the framework has been laid. Health departments still have a long way to go in persuading industry to provide regular in-plant health service programmes, especially in small plants (Miller, 1952).

As might be expected, there has been some dispute between labour and public health agencies in the United States, particularly in the investigation of environmental hazards contributing to occupational diseases. The agreement, in general, however, has been for the factory inspection services to concentrate mainly on accident prevention, while the public health industrial hygiene units deal with the risks of occupational disease and the promotion of general preventive medical services in the plants. When legal action must be taken to enforce correction of an environmental hazard, it is usually, though not always, handled by the Labour Department. In some states, like California, very close working relationships have developed between the labour and health agencies, under which each not only respects the jurisdiction of the other, but also agrees actively to advance the programme of the other by consultation and by referring problems to each other (California State Department of Health, 1952).

In Canada, essentially the same pattern is found as in the United States, with even more authority for the protection of workers against unhygienic working conditions vested in provincial departments of public health (I.L.O., 1951). Factory inspection is conducted by the provincial departments of labour or their counterparts, but regulations regarding specific industrial health hazards, including compulsory periodic medical examinations, are issued by provincial ministers of health. In the Dominion Ministry of National Health and Welfare and in each provincial department of health, there are industrial hygiene divisions which investigate occupational health problems and actively promote the organization of general health services at working places.

South America

Industrialization in South America is relatively recent and legislation protecting labour did not begin to be passed until well into the twentieth century. The dominant pattern originally was exclusive responsibility for industrial health service in the national labour agencies following the patterns of European nations (Spain, Portugal, and France) with which Latin America was culturally tied. With the "good neighbour" policy of President Roosevelt, the influence of the United States grew, and since about 1940 increasing responsibility for occupational health administration has been assigned to the public health authorities.

In Brazil, the Ministry of Labour, Industry, and Commerce has a Division of Industrial Hygiene and Safety, which engages some 25 physicians. These men investigate occupational health hazards, and they also perform medical examinations of workers in certain plants. Owners of large plants (over 500 workers) in isolated places are obliged by law to provide their own medical staff for emergency medical care. The National Department of Health in Brazil has had no official responsibilities in occupational health, except that its training institute includes a three-month course for doctors in industrial hygiene. Plans are under way, however, to organize an industrial health unit in the National Department of Health which would emphasize preventive services (Bloomfield, 1950).

The Argentine, the second largest country in South America, places a great deal of responsibility for occupational health in its health agencies. The Ministry of Public Health has an Office of Industrial Medicine which advises employers and trade unions on industrial health problems (Escarra, 1952). Physicians in this office also examine workers to determine the degree of disability of industrial injuries, a task done on behalf of the National Social Welfare Institute which administers the social security programme. The Ministry of Labour has a Bureau of Occupational Hygiene and Safety which, on the request of trade unions, investigates hazardous conditions and can compel correction, but it does not carry out routine or systematic factory inspection. The Health Ministry's Office of Industrial Medicine also conducts such surveys and advises employers generally on hygienic practices. In addition, it offers training courses for physicians and engineers in occupational health. At the provincial level, little is done in governmental industrial hygiene, except in Santa Fé province where the Health Department contains an active Division of Occupational Hygiene and Safety.

The dispersion of authorities for various aspects of industrial hygiene among different ministries is a feature of several countries in South America. The situation in Chile has been summarized by Bloomfield (1948).

> "The Ministry of Labour has the right to maintain an Industrial Hygiene Section within its Department of Labour, while the Ministry of Health has authorization for a Department of Industrial Hygiene in the National Department of Health. The Bureau of Labour Accidents is empowered to carry on an advisory industrial hygiene and safety programme

among its insured. The Worker's Compulsory Insurance Fund, through its Institute of Labour Medicine, also functions in this field. The Department of Mines and Petroleum has responsibility for the health and safety of workers in mining and allied industries. And, finally, even the municipalities have broad authority in many phases of industrial hygiene."

This dispersion of responsibilities is, above all, a sign of influences to broaden the scope of occupational health service. In the 1930s many social welfare measures were introduced in Chile. As a feature of its social security programme, Chile was among the first nations to require a periodic medical examination of all workers, under the " Preventive Medicine Law " of 1938. These examinations are designed mainly to detect tuberculosis, syphilis, and heart disease and, while they are administered by the social security authorities, they obviously advance the occupational health programme. In 1952, Chile enacted one of the most significant health laws not only in South America but in the world, its Medical Fusion Act. This sets up a National Health Service in which all governmental health services, including industrial hygiene and the medical provisions of social security, are brought under the unified direction of the Ministry of Health. They are to be administered regionally by Public Health Officers, who will be responsible for all categories of health service in their regions.

Predominant responsibility for supervizing industrial hygiene in Mexico, Peru, Bolivia, and Colombia has rested with the Ministries of Labour, but under the influence of the health programme of the Institute of Inter-American Affairs changes are occurring. The primary emphasis of labour agency administration has often been to assure first aid and medical care following injury, rather than the provision of general preventive health services. Administration of the social security laws providing disability payments, and especially compensation for industrial injuries, have occupied major attention. The cooperative *Servicios* developed between the Ministries of Health and the Institute of Inter-American Affairs (I.I.A.A.), however, have begun to organize industrial hygiene divisions with a broad orientation. These divisions, which will eventually be absorbed in the health ministries, promote activities for the prevention of both accidents and occupational diseases, as well as general programmes of tuberculosis and venereal disease control, nutrition, immunizations, health education, and general community sanitation in and around factories. Such activities have been expanding particularly in Peru and Colombia. They are in planning stages in Mexico and Venezuela. In Bolivia, similar programmes are being developed by the I.I.A.A. even with the Ministry of Labour (Bloomfield, 1952).

In South America, as elsewhere, the most advanced work is often done by private industry, especially in isolated areas where the law requires the employer to organize health services. In some of the isolated mines of the Andes there is no community organization whatever for health purposes except that which the company can provide (Diaz, 1951). In this type of situation, occupational health service becomes synonymous with total public health and medical care. There is always a danger of paternalism in activities of this type in the " company town ", which the workers dislike. In order to avoid this tendency and to win the support of the workers, the law in Brazil and Mexico requires formation of joint labour-management committees on safety and health. Encouragement of such committees is the policy of the Institute of Inter-American Affairs.

On the whole in South America, there is a distinct tendency toward increasing participation of public health agencies in the supervision of the health of workers. With this trend, there is a broadening of the scope of an industrial health service from concentration on accident prevention and treatment of compensatable disabilities toward an overall preventive health service, complemented by medical care for general illness.

Southern Asia and Africa

In Egypt a law was passed in 1904 requiring permits for the opening of " objectionable, unhealthy, and dangerous establishments ". It was administered by a Department of Permits with a large staff of inspectors for investigating the physical aspects of all industrial installations. This department was placed in various ministries at different times, and in 1948, as the country's public health programme was gaining strength, it was incorporated into the Ministry of Health. In 1939, a Ministry of Social Affairs was established and within it a Department of Labour. In 1944 this Department was given responsibility for routine inspection of factories to detect health hazards. Recently it engaged three full-time doctors and a small staff of sanitary inspectors in order to develop a programme to prevent occupational disease. Meanwhile the Department of Permits in the Health Ministry, with a much larger field staff, does similar work (Bruusgaard, 1952b).

As in most economically under-developed countries, the great problem in Egypt is the hygienic conditions in thousands of very small shops. Employers of 100 workers or more are required to

provide first aid and minor medical services at the plant, a responsibility usually dispatched by maintenance of a small dispensary staffed by a male attendant with occasional visits by a physician. To supervize health conditions in the small shops, however, a large field staff is required, keeping in close touch with rapidly changing situations. The public health staff of some 700 physicians, engineers, and sanitary inspectors distributed in regional teams throughout Egypt could provide a skeletal framework for doing this task, if some special training were provided and skilled consultant services were available. Industrial accident rates are high, but by far the greatest health problems of the Egyptian worker are the endemic diseases arising from his total living environment—problems for the public health authorities.

In the other Arab countries, governmental activity in industrial hygiene is extremely limited. In Iran, for example, there are labour laws regarding child labour, hours of work, pre-employment medical examinations, working conditions, etc., administered by the Ministry of Labour, but they are not well enforced. The Ministry of Health has been developing interest in the field, as reflected by a recent request for advice from this Ministry to the World Health Organization for technical assistance in the formulation of an occupational health programme. Actually the most effective supervision at the present time is given by a semi-autonomous insurance society, the Worker's Aid Fund. Under the influence of this agency, which handles social security activities, the larger industries provide a limited dispensary service for first aid and minor medical care, usually given by a medical aide (Lewis, 1952).

A somewhat similar situation is found in Turkey, where the most effective controls over health services in industry are rendered by an independent insurance fund, the Worker's Insurance Institute. Legislation in Turkey, since 1930, actually calls upon the Ministry of Health to inspect work places for hygienic conditions and to enforce certain standards. Among these is the requirement that employers of 100 workers or more provide certain in-plant medical services, and that in plants of over 500 workers hospital beds be provided. Turkey is so predominantly agricultural, however, and the limited resources of the public health authorities had to be spread so thinly over vast rural regions, that little attention could be given to the health problems of industry. In 1941, regulations on hygienic conditions in factories were issued by the Ministry of Health and the Ministry of Economics, but enforcement was meagre. Then in 1946 an act was passed providing compensation for industrial accidents and occupational diseases, and giving maternity leave. This was made the responsibility of a newly organized Worker's Insurance Institute, under the general supervision of the Ministry of Labour which had been set up in 1945. The Institute collects insurance funds and exercises considerable authority over health conditions in factories and mines with insured workers. Employers who pay insurance premiums are exempted from providing the medical facilities required under the 1930 law, since the Worker's Insurance Institute is now supposed to provide these services instead (Petrie, 1952). A factory inspection system was also recently established under the Ministry of Labour.

The establishment of independent institutes, with power to collect money and to spend it, is a common approach to achieving stability for a welfare programme in countries where government is subject to rapidly changing fortunes. This device has the effect, however, of setting up a state within a state, and actually weakening the hand of government by depriving it of funds and responsibilities. As industrialization develops in Turkey, the workers in the cities are becoming unionized and make increasing demands for welfare services. These demands are surely sound, but the way that government responds to them, in these relatively early stages of industrialization, will shape the pattern of all health administration in years ahead.

In the colonial countries of Africa, little is done by government in occupational health supervision which is equivalent to the practices in industrialized countries. The private plantations or estates may, however, provide medical services for their workers and follow basic hygienic practices on housing, sanitation, etc., in fulfilment of the requirements of government charters. Regulations on hygienic standards in labour camps may be issued by the Medical Directorate, as in Nigeria (1950). Occasional surveys of the health of workers may be made by the health authorities, like the *x*-ray studies for silicosis in the mines of the Belgian Congo (1950). Factory inspectorates do not exist and any inspection is a responsibility of the medical department in the colonial government.

In the Union of South Africa factory inspection is organized under the Ministry of Labour and the public health agencies have few responsibilities in the industrial sphere (Cluver, 1948). In India there is likewise a factory inspectorate under the Ministry of Labour, but, by force of circumstances, the public health authorities have become involved in the supervision of hygienic conditions in plants.

There is a great shortage of factory inspectors in

India and working conditions in some industries are primitive. There is a medical inspector of factories in the Ministry of Labour at New Delhi, but in most provinces the practice has developed of appointing the public health officers as "ex officio factory inspectors" giving them the right to enter plants and to recommend to the Chief Inspector of Factories the enforcement of corrective measures. The regular factory inspectors look to the Health Officer for guidance and assistance on hygienic questions. It is interesting to observe that this arrangement did not appeal to a foreign industrial medicine authority whose advice was sought in 1946. The Annual Report of the Public Health Commissioner with the Government of India (1946) states that this consultant: "has questioned whether the medical inspection of the factories should be left in the hands of public health officers or whether it should be done by medical men serving under the Chief Inspector of Factories, as in Great Britain. The Committee adopted a note on the desirability of instituting a Medical Inspectorate of Mines and Factories in India". This illustrates well the influence of the older nations, in spite of the efforts of more recently industrialized countries to adjust administrative patterns to local resources and needs.

Some large establishments in India, like the Tata Industries, have set up their own occupational health and medical care programmes which go beyond the requirements of law. As elsewhere in the world, such enlightened managements have advanced the general recognition of needs for occupational health services (Dastur, 1952). The training of medical specialists is being met in some degree by courses at the All-India Institute of Hygiene and Tropical Medicine, under the Ministry of Health. It is significant perhaps that in many countries, where administrative responsibilities rest with labour authorities, training in occupational health is offered by the health authorities. If nothing else, this would indicate the basic identity of industrial medicine with the other fields of social medicine and public health, for which health ministries are responsible.

Western Pacific Region

The industrialization of Japan since 1860 has been associated with the development of a factory inspection system in the Ministry of Labour. The public health authorities have confined their activities to the control of communicable diseases, environmental sanitation, and other traditional spheres. A remarkable network of over 700 health centres for general preventive services has been developed in Japan in the last few years, but their functions do not, as yet, include health supervision of work places (Japanese Ministry of Health and Welfare, 1951). In 1947, Japan enacted a law requiring pre-employment medical examinations of all workers, reflecting a broadening approach to occupational health.

In Australia, industrial hygiene has been developed as a function of the public health agencies. Health services are organized under each of the six state governments, and each state health department contains a division of industrial hygiene. There is also a factory inspection system under the state departments of labour, to which the industrial hygiene divisions are advisory on technical health questions. In addition, these divisions conduct industrial health surveys, give direct advice to industry on the correction of hazards, operate clinics for occupational diseases, and promote the organization of generalized in-plant health services. At the Commonwealth level, in the School of Public Health at the University of Sydney, there is an Industrial Hygiene Unit, with training, research, and advisory functions. In Queensland, the Department of Health and Home Affairs is responsible for overall factory inspection, as well as technical services in industrial hygiene (Cummings, Smith, and Hadley, 1952).

The governmental pattern in New Zealand is similar. Factory inspection and enforcement of standards are carried out under the Department of Labour and Employment, but the health aspects of industry are supervized by the Department of Health. There are four regional medical officers for industrial hygiene, who advise on health hazards and promote medical service organization in the plants. They are assisted by nurses, who help to set up industrial nursing programmes. The regional staff work closely with the factory inspectorate, the local public health officers, and the part-time industrial physicians. They also conduct research into toxic processes, and they train physicians and sanitary inspectors in occupational health (Brown, 1950).

Practices in Indonesia illustrate the approach to occupational health of a nation which has been overwhelmingly agricultural and has only recently gained its independence in governmental affairs. Faced with enormous problems of disease and with dire lack of medical personnel and facilities, the new government is setting out to develop an integrated health service, based on health centres from which both preventive and curative services are given. Among the functions of the public health staff at all levels is the supervision of factory hygiene.

Leimena (1952) regards this as a component part of the sanitary control of the environment. Substantially the same practice is followed in the Philippine Republic (1952) where sanitary inspection of factories and advice in the correction of occupational disease hazards is a function of the Department of Health.

The Hawaiian Islands, being a territory of the United States, naturally adopt the American pattern of having an Industrial Hygiene Division in the Board of Health. This Division investigates occupational disease hazards and advises on their correction ; it receives reports of cases of occupational disease coming before the Workmen's Compensation Division, a practice carried out in many American states. Hawaii is primarily agricultural and a dominant feature of the economy is the large sugar or pineapple plantation. For many years, workers and their families on these plantations have received medical care through a system of salaried physicians and nurses giving complete services, preventive and curative. Since these enterprises have been unionized, the medical programmes, formerly operated entirely by management, are now jointly controlled through collective bargaining (Doyle, 1951 ; Patterson, 1950).

In colonial or formerly colonial countries generally, plantation medical systems are a major source of health service, preventive and curative, for the agricultural population. It is customary for these programmes to come under some surveillance from the Ministry of Health, especially when the law requires that growers provide certain minimum services. This is so in countries like Ceylon or Malaya with their large tea or rubber estates. The health problems of agricultural production are, of course, very different from those in factories, but these programmes are, nevertheless, providing occupational health services in a rural setting. Supervision by public health authorities permits the country-wide application of uniform standards, which are especially important for the control of communicable diseases in tropical areas.

Northern Asia and Eastern Europe

An important event in the development of health services in the Union of Soviet Socialist Republics was the institution of a complete system of public medical services. Health protection of workers is a function of the Ministry or Commissariat of Health, carried out as part of the general system of state-supervised curative and preventive services.

Since 1933 the Commissariat of Health has contained an Office of Safety and Hygiene responsible for factory inspection. Engineers are in charge of this work, checking on all new installations and enforcing standards of ventilation, lighting, and so on. This environmental control is coordinated with the system of industrial medical services by the regional public health officer. In all plants there is a medical clinic of some type, connected administratively with the regional system of polyclinics and hospitals for the general population. When a plant has 1,000 workers or more, one or more full-time physicians are employed ; for smaller plants a nurse is engaged. Any medical care needed is given within the resources of the clinic, whether the illness is of occupational origin or not ; where necessary the patient is referred to a regional health centre or hospital. Since the whole system is supervised by the public health officer, general preventive services are applied to the workers through the factory. The entire medical and safety system is controlled, within each plant containing 50 workers or more, by a Committee for Protection of Work, representing the workers. Problems of occupational disease are tackled through research and consultant service given by a network of some forty institutes of labour hygiene, under the national public health system (*Travail et Securité, Paris*, 1950 ; Sigerist, 1947).

The countries of eastern Europe, coming under the same social system have gradually adopted a similar framework for protecting the health of workers. In 1951, Czechoslovakia reorganized all its health services, formerly dispersed among several governmental and voluntary agencies, under the Ministry of Health. In Yugoslavia, the unified pattern is substantially followed. Each of the component republics has a Department of Health in which one or more physicians serve as " sanitary inspectors for industrial hygiene ". There are also labour inspectors who enforce the general welfare provisions in industry, but the public health authorities are responsible for the prevention of occupational diseases, special supervision of apprentices and women workers, and surveillance over medical services in the plants. The workers receive all types of medical care through the factory clinics or *ambulanta* which are financed by the government as part of the general public medical system. A large factory will have its own clinic, while a group of small factories may be served jointly by one. These clinics provide pre-employment examinations and other preventive work, but they have not yet developed skills at job-placement evaluations. Extra services like dental care, not provided in the state programme, may be given at the initiative and expense of the individual factory (Goldwater, 1952).

In China, since 1949, there has been an intensifi-

cation of health services for industrial workers. Previously, all health questions relating to industry were the responsibility of labour authorities. Today each industry is required to provide certain health services for the workers, according to standards set by the Ministry of Health. General medical services for all conditions are given through the plant clinic (Chu, 1952, personal communication).

Summary

While this review of the structure of governmental activities in occupational health throughout the world is by no means complete, it may be adequate to demonstrate that widely differing patterns are found, and that the system commonplace in western Europe is by no means universal. Such a statement could not have been made before about 1930, but in the last 25 years a marked change has occurred in the scope and objectives of occupational health work. In western Europe, where a century of experience has crystallized certain patterns of public administration rather rigidly, this broadening viewpoint has expressed itself differently from other countries, where the whole structure of social services has been more fluid.

The focus of labour authorities on the prevention of occupational diseases and industrial accidents has played an invaluable role historically, but it fails to meet current needs. The restrictions of this focus, in relation to total sickness absenteeism, have been mentioned. Further deficiencies are illustrated in the customary requirements for notification of occupational diseases under labour regulations. Such notification is usually tied to the requirements of workmen's compensation legislation, which tend to lag considerably behind the changing hazards of modern industry. From the health viewpoint, any ailment that is conceivably related to working conditions, and hence preventable, should be notifiable. Again, the limitation of pre-employment examinations in so many labour codes to young persons and workers exposed to special risks may satisfy certain welfare conceptions, but it fails to recognize that the prevalence of serious, chronic disease—while not compensatable—is progressively greater in the older worker.

The broadening viewpoint in occupational health can be simply described. It has become increasingly recognized that the protection of the worker's health, both for his sake personally and for the sake of economic productivity, requires concern for his total health and for his physical and mental adaptability to his job. This is a great extension beyond the earlier objectives of avoiding occupational diseases and accidents. The latter purposes remain important and, indeed, call for the application of a vast body of technical knowledge but—considering the total health needs of the worker—they encompass only a small fraction of the problem. The size of this fraction will, of course, vary in different industries and in different countries. Mining in siliceous rock, in a country where preventive measures for the control of silicosis are inadequate, will obviously yield a higher proportionate burden of occupational disease and injury than work in a country where vigorous preventive measures are being enforced or in an industry with fewer inherent hazards. Taking industry as a whole, however, it has probably always been true that purely occupational disease and accident constitutes only a minority fraction of the worker's burden of ill-health, albeit a preventable fraction. As preventive measures are instituted this fraction obviously becomes smaller, so that in the economically advanced countries—despite the increased exposure of man to chemicals and machines—the fraction of human disability caused by direct occupational influences drops to only one-tenth or one-twentieth of the total.

The occupational hygienist of the old school, one might say, has been working himself out of a job, in the same way as does the tropical hygienist who has wiped out malaria. But a job remains, if he widens his horizon to encompass the general health needs of the worker. In practical terms, this widening has occurred in stages. A first stage is related to the attainment of industrial efficiency, and a second stage to the achievement of general community health and well-being. In the former stage, the pre-employment and then the pre-placement medical examination is introduced. An effort is made to fit the worker to the job and, likewise, through environmental controls, to fit the job to the worker. In the latter stage, the above activities remain but, in addition, the factory is regarded as one phase of community life through which measures of value to general health may be applied. These measures may, indeed, advance productivity, but even if they do not do this directly, they are justified as means to improved community health.

We have seen how this broadening horizon has been expressed in western Europe through gradual extension of the scope of laws governing factory inspection, through the organization of voluntary societies for promotion of better in-plant medical services, and through the direct initiative of enlightened employers. The pre-employment medical examination and the periodic re-examination have become widely accepted as desirable. A special influence has been exerted by government

beyond its supervisory role when government has become employer. Thus, in the nationalized industries of Great Britain, France, and other countries, particularly comprehensive occupational health programmes have been organized. The trend has been reflected in the work of the various research institutes in occupational health like those in Finland and Yugoslavia, where investigations are made in "industrial physiology", to determine the optimal conditions (human and environmental) for working efficiency.

The trend is also shown in the activities of international bodies. The scope of the conventions and recommendations of the International Labour Organization has significantly changed over the last 30 years. The earlier actions were devoted to promoting protective measures in particular trades or in the use of particular chemicals, like lead or phosphorus. The I.L.O. obviously reflected the interests of national ministries of labour. The more recent actions have concerned general medical examination of young persons, general labour inspection, and the safeguarding of maternity (De Boer, 1952). Under consideration now is a new proposed convention on "Protection of the Health of Workers in Places of Employment". While this instrument does not go so far as to call for the establishment of medical services and general preventive measures in plants, it calls for a wide range of preventive medical examinations. In the World Health Organization, organized in 1948, concern for occupational health has been directed toward aspects other than occupational diseases and injuries (Roemer and Da Costa, 1953).

In other continents the broadening objectives of occupational health work have taken the forms found in western Europe but, in addition, they have found another expression. This has been the increasing tendency to consider the health protection of workers as a branch of general public health work under the direct supervision of the overall public health agency. This change has served to direct attention not only to the task of eliminating occupational hazards, but to promote the general health of workers through the convenient approach of the factory—just as the child's health is promoted through the school. This shifting of official responsibility, as we have seen, is found on every continent in greater or lesser degree.

It cannot be claimed that public health agency administration of occupational health inevitably means this broad approach. In some measure the trend may be due to other reasons, such as the fact that the health ministries are the major resources for skilled personnel in social medicine. In certain instances public health administration may for the moment yield a programme no wider in scope than traditional factory inspection. What is important, however, is that public health administration provides the natural framework for a broader approach—one in which it will easily grow—since the public health agency is, by definition, devoted to advancing the total health of the community. It is less likely to have its aims limited by considerations of injury compensation laws or even the needs of productive efficiency.

Conclusions and Discussion

Developments in social medicine come in response to social needs, but the development of occupational health within public health administration can help to meet needs beyond those that have provided the immediate stimulus. One of the most pressing needs in modern public health is the development of preventive programmes for the adult population, other than maternity services. As communicable diseases are reduced, especially in childhood, the larger disease problems faced by a society tend to become the chronic, degenerative disorders of adult life: cardiovascular disease, cancer, diabetes, and arthritis, as well as mental disorders. It is difficult to tackle these afflictions on a public health basis, but one of the best approaches currently available is through assurance of early diagnosis and prompt treatment. Multiple screening tests given through the place of work are an important method of early diagnosis, and arrangements for prompt treatment can be made through an industrial medical care programme. Insofar as nutrition or personal living habits may provide a key to the prevention of arteriosclerosis, hypertension or other chronic diseases, health education through the factory may be effective. In a word, the work place can be an excellent locale for the promotion of an adult health service, both preventive and curative.

It is also important to consider the administrative relationship of occupational health and of general community health administration. The individual with his family is the common denominator to all health services, but a full understanding of their problems calls for knowledge from many different sources, and effective action requires authority in many spheres. For these reasons, sound application of both preventive and curative health services demands coordination of many different organized programmes at the local level. The local public health officer is the obvious instrument for such coordination, but this is possible for the employed adult only if this officer has authority within the

walls of the work place. The need for unified health administration at the local level has become increasingly recognized by public health leaders throughout the world (Mackintosh, 1952). It is undoubtedly at the root of the current debates on occupational health administration in relation to the National Health Service in Great Britain. In the under-developed countries, even less can the economies support the extravagance of overlapping or uncoordinated medical-social administration.

It should be stressed that coordination of occupational health and public health services at the local level does not necessarily imply a change in authority at the national level. A Ministry of Education or Ministry of Commerce may and does delegate certain authorities to the local public health officer, and there is no reason why a Ministry of Labour cannot do the same thing.

In most countries the control of nuisances created in the community by industry, through river or atmospheric pollution, rests with the public health authorities, even when control of the internal factory environment lies with the labour authorities. In urban life, this problem can take on large proportions, and it should be more effectively handled if the agency responsible for general community sanitation has free access to the interiors of factories.

All countries possess, or are developing, a network of local health administrations to cover their entire population. These local health departments are close to the people, working with community groups on all questions affecting health. They are in an excellent position to keep in touch with local industries in their area—not on the infrequent basis that is inevitable when a national ministry has only a handful of medical inspectors of factories distributed regionally over a large area, but frequently and regularly. In other words, the local health department can provide the community " family doctor " in close contact with the work place, to be aided by the specialist or consultant at the regional or national level when difficult technical problems arise.

This approach has special value in underdeveloped countries where the preponderance of employment is in agriculture or in small shops. The organization of small-plant occupational health services on a cooperative basis is widely recognized as the solution to a difficult problem, and the local public health staff is admirably suited to organize such services. Not that the health officer or public health nurse could render the direct clinical services required in the plants—a point on which there is sometimes misinterpretation—but they could promote and organize such programmes. The practicability of this idea has been demonstrated in several communities in the United States and New Zealand, although the need is doubtless greater in less prosperous countries.

Finally, one may ask how much therapeutic medicine should properly be provided in a health programme centred at the place of work? Obviously the answer will differ in different social systems, depending on the overall national arrangement for medical care. Where most medical service is procured through independent physicians—either paid privately as in America or by insurance as in western Europe—the tendency is for in-plant health services to be limited to prevention and care of minor illnesses, while most therapy is left to the personal physician. In societies where most medical services are rendered through a public system—as in the Communist nations and in many underdeveloped and formerly colonial countries—complete medical services are often rendered through the enterprise (factory or plantation). In either case, there is a need for coordination of preventive services and therapy, if only in the interests of economy for the latter. Social security systems have recognized this need, through their efforts to promote industrial safety and hygiene programmes in most European countries. Likewise, when the health ministry has responsibility for administration of medical care programmes, its officers have a natural incentive to promote preventive health services in industry, and they have the opportunity to coordinate preventive and curative services.

If trends toward the organization of public medical services continue throughout the world, we may reach a time when most medical care will be given through health centres in each community. If this is done, such centres should be closely associated with all factories and work places, having on their staffs physicians and nurses who would be seconded to industry to provide preventive medical services and on-the-spot care in the plants. The latter services might be financed by the industry or by the government, depending on the general economic system. The important point is that the *services* should be coordinated, so that the physician and nurse, seeing the worker in the plant, would be in close professional touch with the physician in the health centre who treats him when he is sick. Similar coordination with the hospital is essential. Such comprehensive, integrated service for the worker and his family would only be possible if all community health services—preventive, occupational, hospital, curative care of the ambulant patient—are administered under a single direction. The public health team of today is trained in the skills of

health administration, preventive medicine, environmental control, and social organization, which are applicable within the factory walls as well as outside them.

There is no intention here to minimize the importance of the classical activities of industrial hygiene, designed to limit the wastage caused by industrial accidents and occupational diseases. In many under-developed countries, which have hardly yet come to recognize their own industrial hazards, this is an important priority. While they are being tackled, however, the whole picture of the worker's health can be kept in mind. One should also keep in mind the need for integration of specialized services in total community health organization.

The necessity of factory inspection remains for various aspects of work which go beyond the strict sphere of health maintenance, such as legislation controlling the employment of children and women, night work, and rest periods. Likewise the general physical arrangements of production processes are important, not only for the sake of accident prevention, but also for the general comfort and morale of the worker. In some countries, the jurisdictional line between the functions of labour and health agencies has been drawn on this basis, with the labour inspectorate covering safety while the health agency covers all other aspects of health. Enforcement of standards in both spheres, however, may be vested with the labour authority.

The labour ministry may claim that there is an advantage in encompassing the problems of the "whole worker"—his wages, hours, working conditions, collective bargaining, as well as his health. The same argument has been made about the "whole child" or the "whole farmer" or the "whole military veteran"—leading to the establishment of independent, vertical health programmes for the child, the farmer, or the veteran. It is these demographic groups themselves who suffer most by isolation from the main stream of skilled professional service and community health activity. Modern medicine and public health are exacting disciplines, requiring special training and skill. Any nation, or certainly any local community, can achieve the best results by vesting responsibility for these services in a single health agency where the best professional talents are concentrated. In fact, by dispersing authorities, administrative funds are dispersed and it becomes more difficult to attract competent men and women to public health or social medicine.

In any event, energetic cooperation among all governmental authorities concerned with the health of people is essential. Exclusion of public health agencies in certain countries from the occupational health domain is not only due to laws and traditions and to a jealous guarding of prerogatives by labour authorities, but also to lack of initiative by public health agencies, failure to exploit opportunities, and rigid adherence to certain classical paths in public health. But, even without new legislation, there are numerous opportunities for health departments to render useful service to industry and to workers in epidemiological investigations, communicable disease control, sanitation, health education, and even in maternal and child health work (Abrams, 1952). Within existing legal frameworks, therefore, much can be improved, as was pointed out recently by the Joint Committee on Occupational Health of the International Labour Organization and the World Health Organization (W.H.O., 1953). As experience in cooperation is gained, laws and practices may be changed to provide the administrative foundation for completing the evolution from factory inspection to adult health service.

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OCCUPATIONAL HEALTH PROBLEMS OF ENGLISH PAINTERS AND VARNISHERS IN 1825

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The publication in 1832 of C. Turner Thackrah's work on "The Effects of Arts, Trades and Professions . . . on Health and Longevity" is justly considered a landmark in the development of occupational medicine in Great Britain. Intended "to excite the public attention to the subject," there is no doubt that this work achieved its purpose. In the medical literature Thackrah's monograph was, of course, not without antecedents. Heretofore, however, attention has not been called to any English non-medical publication dealing with specific problems of occupational health. The purpose of this essay is to direct attention to a small book, which appeared six years before Thackrah's work and dealt with the occupational health problems of one group of workers, namely, painters and varnishers.

In 1825, there appeared at London an anonymous publication entitled *The Painter's and Varnisher's Pocket Manual. . . . To which is added, Statement of the diseases and accidents to which painters and varnishers are peculiarly liable, with the simplest and best methods of prevention and remedy*. This volume was apparently one of a series of practical pocket guides. Thus, the back cover lists two other titles, *The Builder's Pocket Manual* and *The Cabinet Maker's Guide*. The Manual measures $6\frac{3}{8} \times 3\frac{1}{4}$ inches and comprises 215 pages.

According to the anonymous author,

"The object of the *Painter's and Varnisher's Manual* is to give a clear, concise, and comprehensive view of the principal operations connected with the practice of those trades, and to embody in as little compass and as simple language as possible, the present state of knowledge in the arts of painting and varnishing, including all the information derived from the numerous recent discoveries in Chemistry" (p. 5).

"The numerous accidents and peculiar diseases" says the writer, "to which Painters and Varnishers are known to be liable in the exercise of their trade, have suggested to me the propriety of introducing a notice of the chief of these, with their general causes, pointing out the best means of prevention and remedy, and giving proper cautions against the injurious and injudicious attempts at cures too frequently made use of. For the information contained on this head, I am indebted to the kind assistance of a medical gentleman of extensive acquirements, and great experience" (pp. 7 and 8).

It has not been possible to ascertain the name of the "medical gentleman" who provided the information. Nevertheless, examination of Thackrah's book indicates that a number of physicians had observed and recorded various occupational health problems among painters and workers in related trades. Thus, he quotes a Dr. Alcock who reported that

"In an extensive lead factory in the vicinity of the metropolis [London], in which the colic peculiar to such places was formerly very prevalent, that disease has become so rare, that medical assistance has not, for some years past, been required. Many have supposed that the fumes of the lead induced the disease; but the remedy was found by tracing the cause to a more direct source. Workmen are seldom very strict in regard to cleanliness. The probability of particles of the mineral being conveyed from the hands amongst the food was suggested, and an order enforced that before any of the workmen should leave the factory to go to meals, their hands should be thoroughly washed, and that nail brushes should be used to prevent any of the lead remaining where it was most likely to adhere. The success of this plan, under strict superintendence, has been complete" (Thackrah, 1832).

REFERENCE

Thackrah, C. Turner (1832). *The Effects of Arts, Trades, and Professions, and of Civic States and Habits of Living, on Health and Longevity*, pp. 106, 108, 2nd ed., London.

THE

PAINTER'S AND VARNISHER'S Pocket Manual;

CONTAINING

RULES AND INSTRUCTIONS

IN

EVERY THING RELATING TO THE ARTS OF PAINTING AND VARNISHING,

WITH

FULL DIRECTIONS FOR THE PROCESSES

OF

Colouring Flats, Polishing, Gilding, and Japanning;

AND AN EXTENSIVE COLLECTION OF USEFUL AND VALUABLE RECEIPTS: ALSO, A DETAIL OF THE ADULTERATIONS PRACTISED UPON ARTICLES USED IN THE ABOVE ARTS WITH THE PROPER MODES OF DETECTING THEM.

To which is added,

STATEMENT OF THE DISEASES AND ACCIDENTS TO WHICH PAINTERS AND VARNISHERS ARE PECULIARLY LIABLE, WITH THE SIMPLEST AND BEST METHODS OF PREVENTION AND REMEDY.

LONDON:

PRINTED FOR KNIGHT AND LACEY,
PATERNOSTER-ROW,
AND WESTLEY AND TYRRELL, DUBLIN.

MDCCCXXV.

Thackrah (1832) also cites Robert Christison, the toxicologist, to the effect that London painters were reputed to suffer more from lead colic because the men worked longer hours and therefore did not have enough free time to cleanse themselves properly. Obviously, there was an interest in such matters among physicians who came in contact with them.

The health problems discussed in the *Painter's and Varnisher's Pocket Manual* are poisoning with lead, mercury, arsenic, and verdigris; nausea due to the inhalation of fumes arising from such substances as oil of turpentine; and accidents, in particular, burns and scalds. Lead poisoning is discussed most fully under two headings: dry belly-ache and weakness of the wrists. In addition, there is a section devoted to general occupational hygiene. Here the emphasis is on temperance in the consumption of alcoholic beverages. Throughout, stress is placed on prevention (pp. 197–215).

This section is of interest also because it represents an attempt at the health education of a group of workers, and thus deserves a place in the history of health education as well as of occupational medicine. It is against this background that this early contribution to the occupational health problems of painters and varnishers is presented here in full.

DISEASES AND ACCIDENTS TO WHICH PAINTERS AND VARNISHERS ARE PECULIARLY LIABLE

The business of a Painter or Varnisher is generally, and not without reason, considered an unhealthy one. Many of the substances which he is necessarily in the habit of employing are of a nature to do injury both to the nerves and the inside, and great caution and care are required to prevent these from producing serious consequences. Much, however, of the mischief that is done arises from the want of proper precaution; the being ignorant of the symptoms of disorder, or want of due attention to them in the beginning; and more than all, the use of improper remedies, from the being unacquainted with those that ought to be used. I think, therefore, that I shall be rendering an acceptable service to the Painter and Varnisher by mentioning the principal diseases to which his occupation renders him more liable than persons differently employed, with the proper means of remedy; and I shall add some general observations on the best means of preventing, as far as possible, any serious attack of them.

Dry Belly-ache

This disease, the most common and the most dangerous to which Painters are liable, arises with them from breathing in the fumes, and handling the different preparations, of white lead. It is a violent species of cholic, and may be produced by other causes; but when it proceeds from lead, it is always the most obstinate, and the most tedious and difficult of cure.

The first symptoms are, a pain at the pit of the stomach, gradually increasing, and proceeding downwards to the bowels; it is particularly violent around the navel. The person is likewise affected with frequent belching, slight sickness at the stomach, continued thirst, a quick short pulse, a confinement of the bowels, and repeated attempts to obtain a stool without effect.

When some or all of these symptoms are experienced, a strong dose of castor oil should be immediately taken, and repeated till it opens the body freely. If it will not act, calomel pills must be taken

in turn with the castor oil ; and should both these fail to purge effectually, a clyster must also be employed, composed of ten ounces of senna, and three grains of opium in solution. The warm bath, as well as warm fomentations, in flannel cloths, of the lower part of the stomach, are extremely serviceable in relieving the spasms ; and should the symptoms continue, a blister applied to the abdomen may prove useful.

The person affected should be kept as quiet as possible both in body and mind ; he should take no wine, spirits, malt-liquor, nor any kind of solid food, but should confine himself to broth diet, and copious draughts of weak diluting drinks, such as barley water.

Where the bowels are very obstinately confined, and the person is young and of a full habit, it may be advisable to begin with taking from him a quantity of blood, according to circumstances, in order to prevent inflammation.

I have not mentioned the strength of the doses to be employed as purgatives, because that must be determined by the constitution of the sick person, and the manner in which the medicines operate. In a general way, remember never to give too strong a dose at once, as it can always be repeated as often as may be found necessary.

If the remedies I have mentioned prove successful in removing the early symptoms of the dry belly-ache, which will generally be the case, the person who has suffered, on returning to his work, should if possible entirely avoid, for some time, all parts of his business in which preparations of lead are employed. He should also, long after he may seem to feel quite well, keep to the light diet I have mentioned above, or he may bring on a relapse worse than the first attack of the disorder.

This disease is known in some parts of England by the name of the *painter's colic*. Few distempers grow more rapidly worse, and it is of the utmost importance to attend to its first symptoms, for if these are neglected, the most frightful consequences ensue. The violence of the pains increases beyond description ; the outside of the belly feels pain at the slightest touch, and the muscles inside become wrapped into knots ; a difficulty of making water, sometimes amounting to almost a total stoppage, takes place, and the bowels are so contracted by spasm, as scarcely to admit a clyster. If these symptoms proceed, the spasms become more frequent and violent ; and either the costiveness cannot be overcome, (in which case inflammation of the bowels succeeds, and the patient's death is certain), or if his life is saved, he generally remains a victim, in a greater or less degree, to the palsy.

I have mentioned these fatal circumstances, to show the necessity of immediately attending to the first appearances of this dangerous disorder. In an advanced state of it, I do not pretend to prescribe —the best medical assistance must immediately be obtained. The remedies I have recommended are only designed for that early stage of the distemper of which the symptoms have already been described. They may then be used with advantage, and if persevered in, will prevent the danger of severer suffering.

Weakness of the Wrists

This is a partial kind of palsy, which sometimes remains after the dry belly-ache is cured. In some cases, too, it comes on without any previous attack of that disorder, where the injury has been more owing to handling lead than breathing in its fumes.

Where this weakness of the wrists is experienced by a Painter, let him take, three or four times a day, a dose of nitrate of silver, of from one to three grains, according to the manner in which it may operate. Before taking each of these doses, he should also take some castor oil. If it purges him too violently, let a little opium be mixed with the dose, lest bloody stools should be brought on. It is better to give the nitrate of silver in solution than in a solid form.

Where the bowels are so weak as to make any strong purge dangerous, this weakness of the wrists has often been cured by rubbing a drachm of strong mercurial ointment upon them every night and morning, till the mouth became sore. Indeed this will always be found a useful application.

One of the best methods in the weakness of the wrists arising from the handling of lead, is, in addition to the taking of medicine, or the application of mercurial ointment, to make use of a splint, made something like a battledore, fastened under the forearm, and continued to the extremities of the fingers. This has, in many instances, restored the strength of the wrists, even where the weakness amounted to complete palsy.

I have already observed, that confirmed palsy may be the effect of a violent attack of the painter's colic. The remarks, however, which I made under that head apply here. I shall not venture to prescribe for that melancholy state of disease. My object is not to point out remedies for those extreme cases, but to suggest the best means of preventing them.

EFFECTS OF POISONOUS SUBSTANCES USED IN PAINTING AND VARNISHING

These are principally lead, quicksilver, arsenic, and verdigris. Of the injurious effects of lead I have already spoken. Arsenic is found in some particular colours, particularly in *orpiment* and *realgar*, and this circumstance is a strong objection to the use of them. Quicksilver enters into the composition of various amalgams employed in lacquering and gilding. The poisonous properties of verdigris are well known.

It cannot be too strongly impressed upon the mind of the Painter or Varnisher, that mineral poisons of every description are as effectually taken into the system of the body by handling them or inhaling their fumes, as by actually swallowing them ; and that the consequences, though not so immediately fatal, are as certainly injurious. Care should therefore be taken not to handle them more than is absolutely necessary, and likewise, by keeping a thorough draught of air, and leaning as little as possible over such substances during their preparation, to avoid, as much as in your power, the breathing in the fumes arising from them.

But as you cannot entirely escape these, it will be well to know how to distinguish their respective characters. The effects of lead are sufficiently distinguished by the peculiar diseases it produces, which have been noticed before. Arsenic and quicksilver are attended with different consequences. When the former has found its way into the stomach, it will occasion a pricking and burning sensation, with thirst, and sometimes vomiting. A pain will likewise be felt in the bowels, but without producing purging. If, after using colours which contain a mixture of arsenic, you experience any of these symptoms, a little fresh charcoal, powdered fine, in small doses repeated, will be found very serviceable. An emetic should also be taken, and the body kept well open.

The fumes or handling of quicksilver produce, besides the symptoms mentioned in speaking of arsenic, salivation in greater or less degree, bad breath, griping pains in the stomach, and severe purging. White of egg dissolved in water and filtered, and diluted as circumstances require, is one of the best remedies when these symptoms are violent. A very good emetic in such cases, is one ounce of sub-carbonate of magnesia, dissolved in a pint of water ; a glassful of the mixture being taken every few minutes, at such intervals as are needful to produce vomiting.

Verdigris is readily distinguished by its nauseous and corroding effects upon the stomach. If you have reason to think you have suffered from the frequent use of this colour, common sugar, taken in such quantities as to open the bowels frequently, will be found the very best remedy.

I strongly recommend to every Painter and Varnisher, when engaged in any part of his business which requires him to employ a poisonous substance, whether lead or any other, the use of tobacco—I mean *chewing* it. It is the most powerful check to a substance acting to produce spasms by suspending the muscular action in the stomach. In short, tobacco possesses in this respect the advantages, without the danger, of opium, and has been found of the greatest service to persons in the trades above mentioned. At the same time, persons who use it for the purpose I have stated, should be careful not to indulge in the practice too freely, for the excessive chewing of tobacco would not only occasion a feeling of stupid languor, which would unfit a man for exertion, but might in time bring on a disease almost as much to be dreaded as the evils which it is intended to guard against.

Nausea

Oil of turpentine, burnt oils of several descriptions, and some other substances used in painting and varnishing, give out fumes which, though not a poisonous nature, are apt to occasion a slight sickness at the stomach, accompanied with a headache, and a fainting sensation, to persons whose nerves are not strong ; and these effects are frequently felt by young people before they become accustomed to the business. In many cases, removing for a short time from the offensive fumes into a pure air, and drinking a very little spring water, will dissipate these feelings. If they return, some opening medicine or an emetic should be taken, which, if a foul stomach, as often happens, has been the cause, will remove it. But if you are a beginner in the business, and find yourself constantly affected in this manner on such occasions, I would advise you to try for some other occupation ; for a person of decidedly weak nerves will be subject to constant ill health as a painter.

Burns and Scalds

In no business are these accidents more liable to occur to the persons engaged in it, than in of (*sic*) the Painter or Varnisher.

In all scalds and burns, it is of the first importance to apply a remedy at the instant. Spirits of wine or turpentine, applied at the moment, generally prevent the rising of blisters ; if it be rectified spirit it is so much the better. Spirit of wine or turpentine is

decidedly the best immediate remedy when the skin is broke. If the violence or size of the burns or scalds render the application of the spirit in the common way too painful, cover the injured parts with pieces of bladder, softened by dipping them in warm water, and keep the outer surface constantly wetted with the spirit.

When the burn is considerable, fresh yolk of eggs (if spirit is not at hand) applied to it will relieve the pain, and forward the cure. A salve, composed of one part of yellow wax and three parts of olive oil, which you can easily make yourself, and carry about you in case of an accident, will likewise be extremely useful, if applied at the moment of its happening.

Scraped potatoe is very often applied to a scald or burn. Some have pronounced it a certain cure,—others have called it injurious ; both parties are wrong. The fact is, it does nothing towards curing the burn ; *but if applied at the first moment*, it prevents its becoming worse, and relieves the pain. It is therefore very right to apply it, if no other remedy is near, till a better can be procured. Water, however, is almost always to be obtained, and in the absence of other remedies should instantly be had recourse to. The part or parts which have been injured should, without a moment's delay, be plunged into very cold water, or plentifully pumped upon, and an astonishingly rapid change from torture to ease will take place. After the immersion has continued a proper length of time, the parts injured should be covered with linen rags, continually kept wetted with water, and streams of air passed over them from time to time by a pair of bellows, till the person feels a freezing sensation.

Water is always serviceable in burns ; and where the skin is not broken, many eminent surgeons consider it as the best of remedies.

GENERAL OBSERVATIONS

I shall conclude this subject with a few general remarks, principally respecting the diet and manner of living of the Painter, on which indeed his exemption from the diseases which so severely affect many in his trade mainly depend.

He should avoid all acid drinks, such as cider, and effervescing liquors ; and abstain as much as possible from sours, both in food and drink, even the use of vinegar ; for acids have a particular tendency to combine with any portion of lead that he may have imbibed, and will act upon the stomach in a most injurious manner.

When a colicky feeling is experienced by the Painter, he often has recourse to a glass of raw spirits with the idea of obtaining relief. Now he cannot commit a greater error. This feeling indicates the commencement of that dangerous disorder, the dry belly-ache, and spirituous liquors will both bring it on more rapidly, and aggravate the symptoms. There is besides a vulgar, but most mistaken notion, that spirits, taken inwardly, are useful in guarding against fumes of lead, and other poisonous substances. And it is melancholy to see the number of persons engaged in the painting and varnishing line, who, from this false idea, are led to adopt the pernicious practice of drinking drams in the morning, and not unfrequently, from the hold this destructive habit gains upon them, at other times of the day too. Now, so far from this practice being serviceable, I can assure the dram-drinking Painter, that whenever he is attacked by that disease, so dangerous to those in his trade, he will find it rendered far more violent by his previous use of spirituous liquors, and more likely to terminate in inflammation or palsy. Ardent spirits, in a raw state, should never be touched by the Painter ; and when taken mixed, they should rather be weak than otherwise.

I have had frequent occasion to observe that Painters in general are partial to a great deal of solid and highly seasoned food. Now it will be perceived, that the disorder from which they have most to fear, and which is most common among them, is always attended by a confined state of the bowels, from which its principal danger arises. A painter who regards his health should always prefer such food as is light and easy of digestion ; and if he takes any solids, it should be in small quantities, and not frequently. For the same reason, though I do not condemn malt liquor to a Painter in good health, I should advise him not to take it in large quantities at a time, as it is heavy on the stomach. The lead, which he cannot avoid more or less imbibing, has a tendency to make him costive, and his business is not, like some others, accompanied with strong exercise to promote digestion.

I need scarcely remark on the advantages of cleanliness in his person to him, since the handling of preparations of lead is one of the injurious parts of his occupation.

In conclusion, let me once more impress upon him the importance and necessity of TEMPERANCE. The neglect of it in a workman of any other description, *may* bring him to *sickness*, *must* bring him to *poverty ;* but the intemperate and drunken Painter or Varnisher makes the most rapid strides in his power to bring upon himself painful sickness, and, very often, premature death !

MISCELLANY

Preliminary Notes on the Treatment of 50 Cases of Tenosynovitis in Industry*

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The treatment of tenosynovitis in industry has been fully discussed in other papers, particularly by Thompson, Plewes, and Shaw (1951). This paper makes no claim for a new type of treatment except in regard to the patient's capacity for work, which, as far as possible, has not been limited at all and, in our opinion, there has been a very considerable saving both in the period of disability and the time spent on light duty.

Tenosynovitis most commonly affects the wrist. In our series, in 44 of the 50 cases it involved the extensor forearm muscles, and of these in no fewer than 38 it involved the extensor carpi radialis group. The cause was nearly always a repetitive movement, particularly hammering, pulling, and sawing. In the other six cases the tibialis anticus was affected, and in at least three of these was due to direct trauma.

In the past it has been customary for all patients with tenosynovitis seen at this factory medical department to have the affected part immobilized. The condition was reviewed after a week and generally the immobilization was continued for a total of 14 days. During this period the patient was automatically restricted to light work usually of a one-handed nature. This procedure was unsatisfactory, the patient often suffering financially due to loss of bonus earnings, and the firm losing through employing a semi-fit man. It was therefore decided to treat a series by physiotherapy using the services of our two whole-time physiotherapists. The following basic criteria were laid down :—(1) That no case should be labelled as "tenosynovitis" unless a crepitus was palpable on movement. (Cases with local swelling and no crepitus present were excluded from the series. No record was kept of the latter but it is our opinion that they responded extremely quickly to the routine treatment.) (2) That no patient should be placed on light work unless he himself specifically requested this. As a result most of the patients continued during treatment the work which was the primary cause of their disability. (3) That no case was to be considered cured until the patient himself stated that there was no pain or limitation on movement, and that he, in his opinion, was cured. This point is mentioned since clinically, that is, as regards crepitus, swelling, and movement, many cases were considered clear some time before the patient himself was satisfied. (4) That every case taken on or discharged was to be seen by the Works Medical Officer. (5) That every patient should be warned on his first attendance that swelling and discomfort might last for the rest of the day of initial treatment and were the normal result of adequate massage.

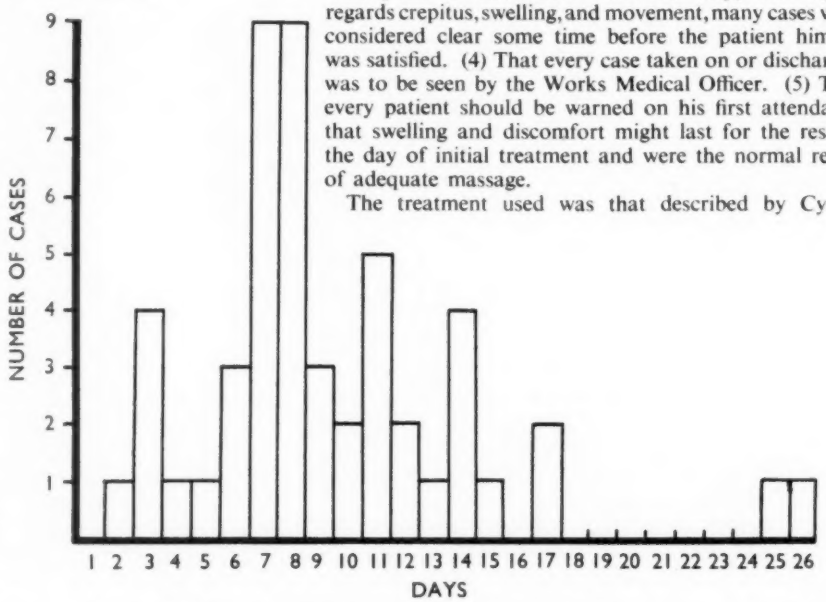

FIG. 1.—Diagram of cases cured showing number of days required, including week-ends, from the onset of treatment.

The treatment used was that described by Cyriax (1947) for long tendons with a sheath. It consists of deep frictions being given transversely throughout the affected area while the tendon is held taut. Thus, for the most usually affected tendon of the extensor carpi

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radialis the wrist was held in full palmar flexion with ulnar deviation and deep friction was applied across the tendon in its full length for approximately 10 minutes. This period normally preceded or followed a similar one of radiant heat, and generally was quite sufficient for both the physiotherapist and the patient.

Treatment was given daily as long as crepitus persisted and with daily or longer intervals afterwards. The results are shown in Figs. 1 and 2.

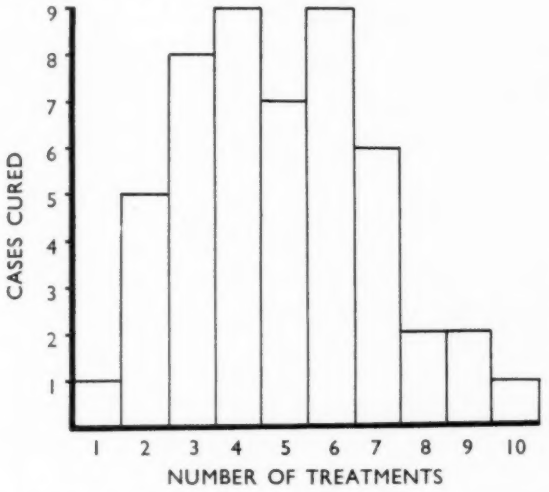

FIG. 2.—Diagram of number of cases cured in relation to the number of treatments.

It will be seen from Fig. 1 that 60% of the cases could be cleared within eight days of beginning treatment and the large majority within a fortnight. The two cases taking 25 and 26 days respectively were both clinically clear after 10 days. Subsequently one patient went on a fortnight's holiday and the other went on to a period of night shifts. Both when seen again were discharged as cured without further treatment. Shift workers, incidentally, are included in the series, although continuous treatment was of necessity interrupted by the hours of their work.

In three of the 50 cases, certificates asking for light work were sent to the men's departments. The other 47 patients all continued at their normal work, the only ruling being that they were asked to inform the Medical Department if such employment were aggravating the condition. No patient did so report although a few ventured the suggestion that they had found repetitive gripping and lifting caused pain in the affected area.

A few cases are worthy of mention. A bricklayer with bilateral tenosynovitis of the forearm extensors was clear in 13 days during which time he continued at full work, the cause as far as could be ascertained of his original disability. A Mr. C, a well known local squash player, reported with a marked crepitus in, and swelling over, the right tibialis anticus. He was playing squash within five days and was discharged after a week. A workman lifting heavy sheets of plate glass was found to have bilateral tenosynovitis. He responded to treatment within 17 days.

Summary and Observations

It is felt that where a full-time physiotherapist is available treatment by heat and massage will produce results unobtainable by splinting, and will at the same time enable the workman to continue in most cases to do his normal work. In this respect the results here have differed from the teaching of Cyriax. The following points were noted.

Palpable crepitus could be dispersed at one treatment if the patient could stand it, and could be resolved in all cases after two to three treatments.

Despite the discomfort of the first treatment, no patient failed to keep his next appointment.

Clinically most cases were clear within four to five days and almost every case was clear to the patient's own satisfaction within a fortnight.

In only three cases out of the 50 was the patient's department asked to arrange alternative lighter work. There were no relapses in the series.

We should like to thank our two physiotherapists, Mr. G. F. Moseley, M.C.S.P., and Mr. J. P. Munroe, M.C.S.P., for all their efforts and enthusiasm in connexion with this short investigation.

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An Occupational Hygiene Team*

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Occupational hygiene is the measurement and control of the working environment with the object of safeguarding the health of people at work. Traditionally in Great Britain the two ways of approaching industrial health problems which have developed are those of the industrial medical officer from within the factory and the factory inspector through the medium of legislation.

The approach of the industrial medical officer includes treatment of accidents and illness occurring at work, provision of first aid services, supervision of general factory hygiene, and advice to management on any question involving medical policy. He is not able, however, accurately to assess and control dust, fume, radiation, noise, and other hazards without the help of engineers and chemists trained in this work. Such help is at present almost impossible to obtain, unless the particular hazard is so spectacular or has such national importance or research interest as to engage the attention of the Medical Research Council or a special university department.

The approach of the factory inspector is, in the main, that of a safety engineer, and it is to his credit that our industry is so well supervised from this standpoint. But the factory inspector is also charged with the prevention of occupational disease, for example in Section 47 of the Factories Act 1937, which deals with the control of dust and fume " likely to be injurious or offensive ". For this task he is not well equipped, since he has no means of estimating whether a dangerous amount of air pollution is present and must depend on making an intelligent guess. He may seek the help of the engineering and chemical branch or call in one of the 16 medical inspectors. The latter are experienced in industrial hygiene but are expected to cover all factories in England, Scotland, and Wales. The medical inspectors have facilities for clinical examination and haematology but are limited in the number of radiographs which may be taken. Samples of the substance in use or of the air contaminant itself can be sent to the Government Laboratory but, because only occasional samples can be analyzed, few, if any, complete and repeated factory surveys can be made.

A situation exists, therefore, in which many health hazards, particularly in small factories, remain undetected and, if known, cannot be controlled with certainty. We believe, in fact, that much occupational disease is never diagnosed or notified, and that discomfort due to working conditions, as distinct from actual illness, is common. These must, in the aggregate, be responsible for considerable loss of efficiency or working time. A few large factories with particular hazards, such as the lead battery manufacturers and the chemical industries, have realized this deficiency and have organized a limited form of occupational hygiene in which engineers, chemists and medical officers work together to assess and control hazards. But most factories remain without any such service.

Other countries, notably the U.S.A., have long had such occupational hygiene services organized by the States. These have been described elsewhere (Nash, 1952), and the capabilities of a fully trained industrial hygiene engineer have been stressed by Herford (1951).

The need for industrial hygiene control in the small factories on the Slough Trading Estate was realized by the Nuffield Foundation and the staff of the Slough Industrial Health Service. One of us (R.J.S., an engineer) was therefore sent to the Harvard School of Public Health for training in occupational hygiene techniques under Professor Philip Drinker. On his return in October, 1950, the occupational hygiene team was formed by the collaboration of the present two writers, the first of whom (P.H.N., a physician) had already been trained at Harvard. Later the team was completed by the addition of a chemist, Miss Joan Bedford. No laboratory was available until January, 1952, when, again through help from the Nuffield Foundation, one was made available to us at the London School of Hygiene and Tropical Medicine. The Occupational Health Sub-Unit, so formed, was linked with the departments of public health and applied physiology of the University of London.

In planning and equipping the laboratory we had to rely largely on our own experience since there was no other unit in the country equipped to investigate any type of health hazard on request. The principle we try to follow is one of service to industry rather than long-term research, and problems are not rejected because they seem either trivial or unlikely to lead to a promising line of research. If a health risk is thought to exist, either by management, employees or ourselves, it is investigated. In this way we are often able to say that no hazard is present, but frequently unsuspected hazards have been uncovered and eradicated.

When such an investigation is completed a detailed report is sent to the firm concerned, dealing with medical and engineering aspects, figures for air concentrations of toxic materials, photographs if helpful, and suggestions for appropriate action. It has been found by experience that advice given in this form is far more effective than verbal arguments in producing a positive response from managements.

Twenty such reports on the use of toxic substances have now been sent to firms, each involving an investigation with only a small number of men at risk. These necessitated the use of many techniques, chemical, physical, and pathological. Sometimes it happened that after much work had been done on a method for estimating a toxic substance the factory would abandon the process before the investigation could be made. Usually

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this was due to a setback in trade ; on one occasion the reason was the employees' objection to the process. The investigations illustrate hazards found in a group of small, modern factories, all of which already had the benefit of an efficient industrial medical service. In older factories, or those with less efficient or no medical arrangements, conditions would certainly be worse.

Some examples of these investigations are given below, not so much for their intrinsic interest as to illustrate the type of work done by a small occupational hygiene team, working only part time.

Asbestos

There are various methods for collecting and counting asbestos fibres. In the U.S.A. the impinger is used as a standard sampling device, whereas in England the thermal precipitator is preferred.

We collect samples in sedimentation cells to give an absolute standard, a method only suitable for high concentrations, and by thermal precipitator to give working standards. The Watson konimeter is used as a guide to the collection of thermal precipitator samples and to demonstrate rapidly to managements the degree of dustiness of the air. It also gives an indication of variations in the concentration of dust and its source.

Sedimentation cell and thermal precipitator samples are counted on a Beck microprojector using a 3·75 mm. objective and a 25x eyepiece at a magnification of 2,500 diameters. Samples are incinerated before mounting and only fibrous particles are counted. We usually compare our counts with the following suggested limits, based on a 40-hour working week :—

(1) Five million particles per cubic foot (equivalent to 175 particles per cc.) of fibrous dust down to 0·9 microns long (American Conference of Governmental Industrial Hygienists, 1952) ; (2) 30 particles per cc. of fibrous dust down to 10 microns long (Vorwald, 1952).

In an operation involving the cutting of asbestos board with a bandsaw, a considerable amount of dust was seen to be produced, even though the saw was fitted with a standard type of exhaust system. Counts showed the operator's average exposure to be 170 particles per cc. of all fibrous dust and 20 particles per cc. of fibrous dust over 10 microns long. Regular medical examinations and chest radiographs of this man, who has been on the job for eight years, have so far shown no evidence of asbestosis. A special type of external local exhaust, in conjunction with a transparent guard, is being developed in the hope that it will both control the dust and reduce the risk of accident. As the dust concentration is so near the accepted maximum limit the continued wearing of a suitable mask has been recommended as a temporary measure.

In another factory asbestos was sieved by hand and added to a solution of bitumen in a tank. Counts in the operators' breathing zones ranged from 3,600 to 11,000 particles, larger than 0·5 microns, per cc. The work was, however, intermittent, and the average concentration for a 40-hour week was in the region of 800 particles per cc.

Medical examinations, including vital capacity readings and chest radiographs of the four men concerned, revealed nothing abnormal apart from the presence of a few single asbestos bodies in sputum samples. Two of the men had been on the process for four years, one for three, and one for two years.

A large measure of control was achieved by using a different grade of asbestos packed in multi-wall paper bags instead of cloth bags. This reduced the aggregation of the material due to moisture, and sieving became unnecessary. Although the tanks were fitted with an exhaust system to remove solvent vapours, this was evidently inadequate for the control of asbestos dust. An external local exhaust system was therefore added and, as a result, dust concentrations fell to the region of 740 particles, larger than 0·5 microns, per cc. The duration of the operation had now been shortened by the elimination of sieving so that the average concentration of dust in this size range was estimated to be 30 particles per cc. for a 40-hour week. Alterations were then made in the design of the exhaust hoods which resulted in an increase of air velocity over the operation up to 150 feet per minute. Average concentrations fell to less than 10 particles per cc. and the process was considered entirely safe.

Exhaust systems in factories are often installed without preliminary measurements of the quantities of solvent or dust which they will have to remove, and no subsequent check on their effectiveness is made. For this reason they are frequently over-elaborate or almost useless. In one factory where many workers were potentially exposed to asbestos dust, conditions were found to be safe whether the very extensive exhaust system was in use or not. In practice it reduced the dust count by only 10%.

In another process eight girls were engaged in dusting down an asbestos product with hand brushes. The amount of dust produced was very small, but no less than 12,500 cubic feet of air were withdrawn from the building by the exhaust system every minute. No provision was made for heating the incoming air and for this reason the operators complained of cold draughts in the winter. The air removed by the exhaust system was passed through bag filters before discharge and this filtered air was found to contain a negligible amount of asbestos dust (less than 20 particles of all sizes per cc.). It was therefore recommended that 100% recirculation of air be permitted in cold weather.

This particular system was unnecessarily elaborate and a far cheaper installation would have sufficed.

Benzol

In a factory producing steam glands, oil seals, and other packings, four men were engaged on a process involving the use of benzol (90% benzene C_6H_6). They had been observed by Dr. M. E. M. Herford (appointed factory doctor) and one was found to be suffering from chronic benzene poisoning. He had no symptoms but a blood count showed total white cells to be 4,800, of which 29% were polymorphs. Although he has been

removed from contact with benzol for two years, his polymorph count is still low.

Two other men showed transitory depression of the polymorphs in one count only.

As soon as this hazard was discovered, an environmental survey was carried out and the concentration of benzol in the air measured at the various operations in the department. The principal method used was that of Siegel and Burke (1939), but the D.S.I.R. method (1939) and a Poole explosimeter were also used for comparison.

General room concentrations of benzol ranged from 45 to 460 p.p.m. and breathing zone concentrations varied at different stages of the process from 60 to 600 p.p.m. (The threshold limit for benzol accepted by the American Conference of Governmental Industrial Hygienists, 1952, is 35 p.p.m.)

An exhaust system was then installed and, as a result, the air concentrations of benzol, both in the general atmosphere and breathing zones, fell to the region of 15 p.p.m. Occasional brief exposures to concentrations as high as 300 p.p.m. still occurred. Urinary sulphate ratios (conjugated sulphates : total sulphates), determined on urine specimens from the operators, have not been above 2 in 10. This shows that some absorption of benzol is possibly still occurring (Goldblatt, 1951) but conditions are undoubtedly very much improved.

In another factory, where dry batteries were made, certain components were dipped in benzol and allowed to dry in a brick chamber. About 150 gallons of benzol were evaporated daily into this chamber which was exhausted and the fumes passed to a recovery plant. It was necessary for the operator to enter the chamber every few minutes to move the components along so that the chamber could be completely filled. This appeared to us to be a very dangerous exposure. Air measurements confirmed this, the concentration of benzol in the chamber being over 1,000 p.p.m. and probably of the order of 4,000 p.p.m.

Blood counts carried out on the seven men concerned revealed the presence of hypochromic anaemia with some macrocytosis in one of them. As he gave a history of past anaemia it was difficult to assess the role which benzol played in this, but he was given a job away from the process. Three of the operators have at some time shown transitory low polymorph counts (i.e. less than 2,500 polymorphs per c.mm.).

Detailed suggestions were made to the management as to how the process could be arranged so that the operator need never enter the chamber. These were carried out and the process is now safe.

Trichlorethylene

In a factory where paper was laminated on Dickson machines the adhesive was changed to one containing polyvinylacetate with trichlorethylene as a solvent. After a few days we had an urgent call from the firm saying that employees were being affected by the fumes and that one had " passed out ".

A visit to the factory on the next day showed that the adhesive was spread by the machine on a roll of plastic which was pressed on to a sheet of card between two rollers. To ensure rapid drying, one of these rollers was gas heated and this resulted in the evaporation of a large amount of trichlorethylene. The air smelled strongly of this substance.

Six operators were interviewed and urine samples were taken from four. At the same time air samples were taken for the measurement of trichlorethylene. The chief complaint was of difficulty in keeping the eyes open and of falling asleep during the lunch break and on reaching home. Examples were a man who had sat down to watch television and promptly fallen asleep until wakened by his wife at bed time, and the young girl who was reported to have " passed out ". She had arranged to spend the evening at home with her boy friend and, though he was present, she slept solidly for four hours and had to be wakened at midnight to say goodnight.

Evidently a considerable hazard was present and the air samples and urinary trichloracetic acid values confirmed this (Table 1).

TABLE 1

ANALYSIS OF TRICHLORETHYLENE IN AIR AND TRICHLORACETIC ACID IN URINE

Operator	$CHCl=CCl_2$ in Breathing Zone (p.p.m.)	Trichloracetic Acid in Urine (mg./l.)	
		Time of Exposure	One Week after Exposure Ceased
A	390	486	12
B	250	334	24
C	—	153	29
D	—	39	24

General atmosphere 10 ft. from machine 200 p.p.m. $CHCl=CCl_2$
Concentration close to roller .. .. 1,460 ,, ,,
Threshold limit .. .. 70 ,, ,,

The threshold limit accepted by the American Conference of Governmental Industrial Hygienists (1952) is 100 p.p.m. for a 40-hour week. The average working hours in this instance were 60, so that it was advisable to take 70 p.p.m. as a maximum allowable concentration. By this standard air concentrations were many times the safe limit. The urinary trichloracetic acid level was also very high. A figure of 70 mg. per litre has been mentioned as the level at which signs of intoxication are likely to appear and the desirable limit is probably about 6 mg. per litre (Ahlmark and Forssman, 1949). There were appreciable quantities of trichloracetic acid still present in the urine samples one week after the process had been stopped. Normal urine, measured as a control, contained none.

As soon as the measurements had been made the use of the particular adhesive was discontinued and another which did not contain trichlorethylene temporarily substituted. Plans for a suitable exhaust system, with suggestions for the recovery of the solvent, have been submitted to the firm and are being put into effect. As soon as the exhaust system is installed, further air concentration readings will be taken to check its effectiveness. Since one roller is gas heated there is a theoretical possibility that phosgene might be formed. Measurements will therefore be made for this also.

Lead and Antimony

A small study was made of an operation in which a man was working up to 12 hours daily casting a lead-antimony alloy (95% lead, 5% antimony). He had made no complaints but it was felt that a health hazard might be present.

Medical examination revealed nothing abnormal. The red cells showed no stippling. The urine contained 0·13 and 0·08 mg. of lead per litre on two occasions, values which are below the acceptable limit of 0·2 mg. per litre for lead workers. No coproporphyrin was detected.

Air sampling was carried out by a number of small sampling units, drawing air through filter paper at 1 litre per minute throughout most of the working day. Ten-minute samples were also collected by a larger unit at 3 cubic feet per minute. By this means variations in concentration could be detected and integrated to find an average value. The mean concentration of lead was found to be 0·08 mg. per cubic metre and that of antimony 0·87 mg. per cubic metre. The threshold limit for lead in the air is generally taken to be 0·15 mg. per cubic metre and the operation therefore appeared safe from this point of view. The probability of the safe limit being exceeded was calculated to be less than 0·1%. The concentration of antimony was, however, higher than the threshold limit now accepted in the United States of America of 0·5 mg. per cubic metre, although no ill effects could be detected in the operator who had been employed on the process for 18 months.

Recommendations were made for a simple improvement in the ventilation system, which has now been carried out. It is interesting to note that although lead was the main hazard suspected, since it formed 95% of the alloy, it was the antimony which was found to be present in undesirable amounts.

Air Pollution Outside the Factory

A complaint was received from a factory about fumes which emanated from the exhaust system of a nearby magnesium foundry. It was said that these were irritating to the nose and throat, and caused corrosion of bright metal parts.

The air was sampled for aldehydes, carbon monoxide, fluorine, fluorides, sulphur dioxide, sulphates, and total acidity. With the exception of sulphur dioxide, measurable amounts of all these pollutants were found in the air immediately outside the factory. In only one case, that of sulphates, was the concentration above the threshold limit. The total acidity of the air was, however, fairly high, 5·1 mg. per cubic metre calculated as H_2SO_4. Spot tests carried out for nitrates, nitrites, phosphates, chromates, and esters were negative.

It was thought that the acidity of the air certainly explained the corrosion of tools and other metal parts in the factory but we were unable to say definitely if any risk to health were present. As in the case of fog, too little is known about the possible synergistic effects of small quantities of many irritants in the air, and the chemical changes which may occur in them through the effect of atmospheric conditions or sunlight, to give an opinion with any certainty.

Chromium Plating

It is well known that in chromium plating there is a risk of ulceration and eventual perforation of the nasal septum for which a special nose ointment is prescribed in the regulations as a preventive. This ulceration can only occur, of course, if there is a sufficient quantity of chromic acid mist in the air breathed. In order to reduce this, exhaust ventilation is applied to the plating bath, and foaming agents are occasionally used to minimize generation of mist.

The generally accepted safe limit is 0·1 mg. of CrO_3 per cubic metre of air for a 40-hour week. We have measured the concentration of chromic acid mist over several plating baths in small factories and have usually found it to be below this limit. In such cases the use of a nose ointment is probably unnecessary.

The chromic acid is collected in distilled water by the midget impinger and estimated by a colorimetric reaction. This technique is so simple that it could easily be carried out by laboratory technicians, safety officers, or other responsible people, and would give a definite indication of the safety or otherwise of a particular bath.

General Factory Hygiene

Minor hygienic improvements in factories often bring about a considerable increase in the comfort and well-being of employees. Under this heading we include such things as improvements in lighting, heating, ventilation, canteens, toilets, and first-aid facilities. Recommendations are best made in writing and, if they are extensive, a full report is sent in the same way as for a health hazard. The following example may be of interest.

Conditions in a plant for the manufacture of "ice lollies" were considered poor by the District Inspector of Factories who referred the firm to us for specific advice. The factory was centred round a large brine (calcium chloride) freezing bath. At one end was a defrosting tank which gave off large quantities of steam. Everything was dripping wet from condensation, the floor slippery and covered with waste material, and the employees, clad in street clothes, worked in a haze of steam. There had been dermatitis among those working at the bath; cloakroom and first-aid facilities were poor, and the toilets needed many improvements. The management were, however, anxious to improve conditions and asked for advice as to the best procedure.

A survey was carried out which included records of air temperature, humidity, air movement and radiation in many parts of the factory, and photographs of situations needing improvement. The relative humidity was found to be 84% (air temperature 65° F.). The report to the management recommended installation of a polished canopy with an exhaust system over the two baths to reduce condensation, improvements in heating, seating, floor drainage, and salvage of waste material. Also suggested were the provision of a cloakroom, improvements to toilets, the wearing of white work

clothing, protective clothing and barrier cream for the brine workers, and detailed advice on first-aid services and equipment.

Most of these recommendations have now been put into practice and conditions are very considerably improved.

Conclusions

This paper describes some of the investigations which we have carried out in a group of small factories. Besides this work a very large number of smaller problems have been dealt with. These involved giving advice on such things as general and local ventilation, lighting, heating, eye protection, skin protection, respirators, protective clothing, handling of radioactive substances, first-aid for special purposes such as bitumen and hydrofluoric acid burns, and accident prevention. In addition considerable work has been done outside the Slough area, sometimes for large concerns such as British Railways and London Transport. Some requests for help have had to be refused owing to pressure of work. This has been done with great regret since it is a principle of the team to tackle any problem which appears to constitute a health risk in any particular factory, unless it is too extensive for a unit of our size.

Two conclusions may perhaps be drawn. The first is that since this amount of work was necessary in a group of comparatively modern small factories comprising less than 15,000 workers in all, there must be many thousands of dangerous, or at least uncomfortable, situations in other parts of the country which could be put right by the application of known industrial hygiene techniques. Some investigations have admittedly been done in which no hazard was revealed. Such enquiries help to promote good relations in industry by removing from the minds of employees suspicions that their work may be unhealthy. Scientific evidence is acceptable to both sides where verbal reassurance, even from a factory inspector, may fail to convince. Some situations, however, have proved to be dangerous, perhaps even to life, such as the benzol and asbestos exposures reported above. Others, like the trichlorethylene exposure, were at least very uncomfortable.

The second conclusion is that to deal adequately with these hazards very close cooperation between physicians, engineers, and chemists trained in this work is needed. We have been particularly fortunate in starting as a small team, since closer personal cooperation has been possible than might have been in the case in a larger unit. We prefer to visit factories together so that an immediate appraisal of the problem can be made from all points of view. When separate surveys have been conducted we have invariably agreed regarding the presence or absence of a hazard and the form which any investigation should take. Such teamwork between different specialities has long been practised in medical research ; it is just as necessary in occupational health.

We should like to express our thanks to Dr. A. A. Eagger, and Dr. A. Topping for giving us every encouragement and facility, to Professor J. M. Mackintosh and Professor G. P. Crowden, for support in difficult times, to Dr. T. Bedford for much wise counsel, and to Professor Philip Drinker for teaching us the principles of this team work.

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The first conference of the recently formed British Occupational Hygiene Society will be held at the London School of Hygiene and Tropical Medicine on Monday, November 2, 1953.

The Sewerman at Work*

ANDREW MEIKLEJOHN

From the Department of Industrial Health, University of Glasgow

Since the publication, just over two years ago, of the Report of the Dale Committee on Industrial Health Services in Great Britain discussion and controversy have been mainly concerned with two emerging problems, first, the medical supervision of persons employed in small factories and, secondly, in non-industrial occupations. Dr. James Bell, a member of the staff of the Medical Officer of Health, Glasgow, in this admirable study of the sewerman at work has opportunely directed attention to a small non-industrial group, indeed one almost overlooked as an occupation except perhaps casually in relation to Weil's disease.

At the same time he has demonstrated what valuable field researches, not as specific projects but as part of daily practice, are available to industrial medical officers. The whole scheme in its planning, method, execution, analysis of results, conclusions and practical recommendations for preventive measures mark the author as one who has well learned the proper outlook and practice of occupational medicine.

The investigation, which embraced environmental, social, clinical, and laboratory studies with special reference to occupational hazards, occupied two-and-a-half years and directly concerned 42 sewermen, the total personnel employed in the maintenance of the 800 miles of public and common sewers in Glasgow, an industrial city of 1,089,555 persons.

Sewers and Sewage

To most of us sewers are pipes of various size but this, as described by Dr. Bell, is a very simplified conception of a very complex system.

> " Public and common sewers vary in size from pipes measuring 9 inches to 2 feet in diameter, to stone and brick sewers 2 feet 9 inches to 4 feet 6 inches in height. Most Glasgow sewers are about 3 feet in height. Among the factors preventing the construction of self-cleansing sewers are the nature of the subsoil, the geography of the City and the amount of railway tunnelling within its boundaries. Thus periodic silt removal is necessary to ensure the free flow of sewage. Access manways are located at intervals of 20 to 200 yards, usually 60 to 80 yards, along each sewer."

Likewise sewage is generally regarded as water-borne human excreta, whereas to the sewerman in large industrial areas trade wastes of diverse nature and composition are the important constituents.

> " Engineering works contribute oils and grease as well as pickling acid, cyanide and suds, while garages are a common source of paraffin, petrol and diesel oil. From chemical works weak acid, weak alkali, spent carbide, resins and other materials enter the sewers. Ammoniacal liquors containing phenol and tar compounds gain access from steel works and gas generators. The paper industry and wool scouring factories produce alkaline soaps while the offensive trades provide grease and other animal products. Although the discharge of materials liable to cause damage to the sewers is prohibited by legislation, enforcement is difficult and such materials are found from time to time."

The sewers are the working places of the men and the sewage, constantly varying in quantity and composition, determines the environmental conditions during working hours.

Sewermen

The sewermen, 42 in number, were in the age range of 35 to 64 years. There was continuity of employment and several had followed the job for over 25 years. Retirement from the job, usually in the early fifties, was premature and as a rule on medical grounds. All were married and wages ranged between £5 10s. and £6 15s. for a 44-hour week, a rate of pay among the lowest for adult males in Great Britain today.

Most had at least three children and about 50% lived in overcrowded houses without a bath.

The method of selection for the job is of interest ; " all are recruited from the general labour force engaged in road repairing in the City. They are observed at work for several years and when a vacancy arises in the sewerage squads then a man who has proved his worth is selected."

As a group they were good citizens, of cheery disposition and almost fearless. Team spirit among them was high and indeed they regarded themselves as a *corps d'élite*, picked men.

The Working Environment

Dr. Bell assisted at various times in the work and so learned through personal experience the actual conditions and demands of the work. Working space was very cramped and involved severe physical strain and adverse postures. Within the sewer all was inky blackness and deathly silence. The air was still and damp and vitiated by the infinite variety of smells, of tarry compounds, paraffin and decaying vegetable or animal matter. Fortunately, however, the olfactory nerve quickly adjusts itself to most of these odours so that they are endured almost unperceived.

Hazards of the Job

These include accidents, specific occupational diseases, infectious diseases, and postural strains.

Among accidents are drowning, physical trauma, and gassing by carbon monoxide, benzine, and sulphuretted hydrogen. Specific occupational diseases include leptospirosis, dermatitis, conjunctivitis, and miner's nystagmus.

Leptospirosis was the subject of special investigation. Departmental records revealed that between 1910 and 1950, 28 men contracted this infection, 23 of them since 1925. The case mortality was 28·6%.

* The Relationship between Occupation and Health as seen in Glasgow Sewermen. By James Bell (1953). *Trans. A.I.M.O.* 2, 141.

The Sewerman at Work : *Report of the Investigations into the Health and Conditions of Work of Glasgow Sewermen.* (1952). The Highways Committee, Corporation of Glasgow.

"In order to protect the sewermen certain special arrangements have been made. Each man is provided with a card on which are his name, address, occupation, notes advising washing of hands before meals, consultation with a medical practitioner as early as possible in any illness, and recommending that the card should be shown to every doctor treating the sewerman. By arrangement with the local general practitioners and at the request of the Master of Works, I visit each sewerman who is off sick. This precaution is taken so that a diagnosis of leptospirosis can be made as early as possible. At such a visit a sample of blood is taken and submitted for a Schuffner test."

Routine Schuffner tests on all the employees revealed serum changes suggesting a previous undiagnosed attack of the disease. Moreover, preventive vaccination has been introduced in an endeavour to protect the men against the possible serious effects of any future natural infection.

"The working posture of sewermen, dictated by limitation of working space, causes very great strain on the lower part of the spine. Lifting and pulling are done with the back acutely bent and hence low backache is common among sewermen."

Dr. Bell found evidence of osteo-arthritis of the lumbar spine and he is further of the opinion that because of the working posture conditions of the back, which in most types of employment would cause little discomfort, produce major disability in sewermen.

The average annual sickness loss of time per sewerman employed is about two weeks, which, relative to other Corporation employees, is not considered to be unduly high. The analysis of sickness by cause is summarized in the table.

The great merit of the enquiry is revealed in the recommendations which Dr. Bell felt justified in submitting for action. (1) Improved ventilation in sewers; (2) improved lighting in sewers; (3) review of trade wastes entering sewers; (4) improved rodent control in sewers; (5) washing and changing facilities (use might be made of the new cleansing department depots as an alternative to building new ablution centres); (6) improved working clothing; (7) laundering of working clothing; (8) use of mechanical transport for equipment; (9) periodic medical examination of sewermen (say annually); (10) recruitment of men under 35 years of age; (11) limitation of service as sewermen to not more than 20 years; (12) policy with regard to retirement of sewermen found unfit for further service in the sewers. After 20 years of faithful service in this arduous work it does not seem right that men should be left stranded at an age in the middle 50s with only a small superannuation pension on which to plan a family budget. In the past, many sewermen, still fit for certain types of work, have been condemned to unemployment, often for the first time in their lives, because of this lack of a policy.

Local authorities throughout the country are large employers of labour including clerical workers, skilled artisans, and labourers and office cleaners. In relation to these employees the local authorities have an unrivalled opportunity for the full practice of occupational medicine and the promotion of health through effective medical supervision and maintenance of good environmental conditions. Superannuation examinations do not constitute the whole of occupational medicine.

TABLE

PERCENTAGE LOSS OF TIME AND PERCENTAGE NUMBER OF CASES DUE TO DISEASE GROUPS IN GLASGOW SEWERMEN IN 1945–50

Disease Group	Percentage of Total Absence	Percentage of Total Cases
Accidents	0·7	2·3
Alimentary tract disorders	25·8	18·2
Genito-urinary system	4·0	4·5
Infectious diseases:		
(*a*) Leptospirosis	20·2	11·4
(*b*) Infectious parotitis	2·1	2·3
Nervous disorders	15·7	4·6
Respiratory diseases	5·4	13·6
Rheumatic conditions	22·3	36·3
Skin diseases	3·8	6·8
All Groups	100·0	100·0

Health in the Army*

A Review by

SIR ALEXANDER HOOD

Late Director-General Army Medical Services

The application of the principles of occupational medicine to any group or industry is undoubtedly much simpler and more effective when the group is properly disciplined. *The Report on the Health of the Army*, 1946–48, provides many examples of how from his recruitment to his return to civil life the soldier and his family are carefully guarded against all the ills that can be foreseen.

The army as a career for a doctor is frequently called unattractive because of its lack of clinical opportunities, but this report shows that while there is a great deal of clinical material and great scope for certain clinical specialities the main emphasis of the medical services of the army must be on prevention in its widest sense rather than on salvage. The primary object of the Army Medical Service is to ensure that as many fit men as possible are at the disposal of commanders—and in war " to keep as many men at as many guns for as many days as possible ". And when the army talks of fit men it does not mean that they are just not ill : it means that they have been brought by every means possible to the highest standard of mental and physical well being and that they remain so.

The Man for the Job

In the army, unlike in most other industries, the recruit arrives in large numbers, and at one time was treated *en masse* as a new entry. Things are very different now. The physical and mental requirements of each branch of the service have been assessed and the aptitudes necessary. So the recruit has a battery of tests, and his selection for a particular form of training is decided on sound principles based on experience. Later in this article an example of how the medical services have taken part in this work will be given. Meanwhile, let us look at the system of grading of physical and mental fitness now used—the so called " Pulheems " system, first used by the Canadian Army during the last war. This system is based on a man's functional capacity rather than on the presence or absence of defects in his make-up and it is very fully described in the Report. But while the system is good, and an improvement on any previous method, there were, at the date of this report, inadequate tests for physical efficiency. More important still no method had been found, and I do not think it has yet been found, to correlate the interaction of physical and mental efficiency and stability on each other and on a man's functional capacity. No tests can differentiate the man capable of winning a V.C. while suffering from dysentery from the man whose functional capacity sinks to zero with a cold in the head or a blistered heel. But that is asking for perfection and the broad general knowledge of their employees desired by the army authorities is furnished by the Pulheems system in good measure.

If it finds in them the basic qualities which by past experience are known to be a good foundation, the army training is designed to improve the mental outlook : to develop the will to give of one's best under the worst possible conditions so that eventually each recruit is convinced that he belongs to the best platoon in the best company of the best battalion in the best army in the world. Emphasis is laid on the mental outlook, for as the spiritual is to the material, so the mental is to the physical in the ratio of 3 to 1 ; care for the mental and you automatically improve the physical. This is man management in a nutshell whether it be in the army or the mine, the office or the factory. Employers with imagination learn quickly, others never, but the Brigade of Guards or the Royal Marines provide the most striking examples of the success of such methods.

Physical Development Centres

The report gives some account of the work done at these places. They were originally concerned with the building up of the substandard recruit and later also with preserving the trained soldier who was at risk of breaking down. No one who visited these centres could fail to be impressed, not so much with the excellent work done on the physical side but with their great value in building morale. The entry came as unhappy potential failures, they departed happy, alert, looking the world and its difficulties straight in the eye, ready and eager to serve.

Their value was due in the main to the type of men forming their staff. They must be enthusiasts with both feet on the ground, and if some are well known in the field of sport, cricketers, footballers or athletes, so much the better. Such establishments may not be needed now but those concerned with the problem of juvenile delinquents might well find help and inspiration in the study of the methods used in physical development centres.

The Feeding of the Soldier

If an army marches on its stomach then the 1948 army at home must have had about half the range of that of 1939, for the daily ration of meat had been cut from 12 oz. to 3¼ oz., of bacon from 2 oz. to $^{5}/_{14}$ oz., and cheese from 1 oz. to ½ oz. with some slight gains of ¼ oz. of fat and 1 oz. of sugar. The food habits of the whole nation had changed and the army also conformed. One looks back some 40 years nostalgically to the mess tables of those days, but the soldier was then conditioned to a totally different food intake. But if his ration is less abundant it is made better use of and the catering, cooking, and serving have been improved out of all recognition, and waste cut to a minimum. At the period covered by the Report the soldiers' ration did not provide sufficient calories for his needs and he was supplying that deficiency by purchases of food from his own pocket. Now one of the attractions held out to the potential soldier has always been that he has everything

* Based on *The Report of the Health of the Army*, 1946–48. The War Office. (Pp. 116 ; 32 tables.) London : H.M.S.O. 1952.

found and his pay is really only pocket money, but if hunger forces him to supplement his ration to the extent of purchasing about a quarter of his necessary food then it is to be hoped that either this has ceased or that he has been compensated in other ways.

Prevention of Specific Diseases

The test of methods of prevention comes in their application in the face of epidemic risks. This Report shows how the army was completely and absolutely protected from cholera during the disastrous epidemic in Egypt in 1947. Lasting from September to December there were over 20,000 cases and over 10,000 deaths in the civilian population. British troops to the number of many thousands stationed in the area of the epidemic had not one single case. As the army notice about cholera said " You eat or drink cholera ", and the army proceeded to see that none of its personnel ate or drank it. How it did that is detailed in the Report ; the army notice ended with the words " Don't flap ". This terse, idiomatic injunction has a sound physiological basis for fear diminishes the secretion of hydrochloric acid in the stomach and one of the barriers to infection by ingestion is an adequate gastric acidity.

The army in Egypt was not compulsorily inoculated against cholera and mass inoculation was not begun until the epidemic began to decline although special personnel at greater risk were offered inoculation. It is interesting to reveal the reason for this and it is not mentioned in the Report. Inoculation has been the subject of a great deal of propaganda in the British Army, in which inoculation against typhoid fever originated through Wright and Leishman. But the British Army was the only army engaged in the last war in which inoculation was not compulsory. However, the intelligent British soldier has accepted inoculation as a useful method of prevention and indeed some, and especially the families of soldiers, have come to look upon it as almost a complete protection against a disease. Consequently it was felt by the medical authorities in the army in Egypt that if inoculation against cholera were offered *en masse* or made compulsory at the beginning of the outbreak it might lessen the rigid compliance with the other means of prevention such as the boiling of milk and the prohibition of the eating of uncooked fruit or vegetables. That this was well founded is borne out by the fact that some of the personnel of the army asked to be inoculated "so that we needn't boil the milk". Popular opinion at home, both medical and lay, was, however, in favour of inoculation and for policy reasons this was eventually advocated for all.

This experience proves conclusively that a highly disciplined body of men, women, and children can be protected against a disease where the methods of protection are known and can be enforced even in the face of a raging epidemic. What a difference from the days of cholera camps in India :

> " We've got the cholera in camp—it's worse than forty fights.
> We're dying in the wilderness the same as Israelites.
> It's before us and be'ind us and we cannot get away,
> And the doctor's just reported we have ten more today ".

The Place of Intelligence and Aptitude Tests

There is one further principle of occupational medicine which the army was applying with some success, the principle of fitting the man to the job. Each occupation requires a certain minimum of intelligence and ability to learn and often the aptitude for certain skills. The services of psychologists and psychiatrists were used to devise means whereby the best use of the human material could be made. (A very full account of the methods employed in all the services will be found in the Report of an Expert Committee on the Work of Psychologists and Psychiatrists in the Services published by H.M. Stationery Office in 1947.) The need for making sure that the best use is made of all recruits is very evident when it is realized that 13% of the army's recruits fell into the lowest intelligence group in terms of ability to learn, S.G.5 ; the waste of time, effort, and money involved in training unsuitable recruits must at all costs be avoided, especially in war. This was well illustrated in the selection of men for training as parachutists. The failure rate in the training of parachutists was at one time in the war 20%. By means of grading by psychiatrists a very accurate prediction of the failure rate was made from 3% in grade I to 46% in grade V. It was then the duty of the executive to decide which grades should be trained, i.e. what percentage of failures it was economical to accept. Moreover a follow-up showed that whereas 39% in Grades I and II had been promoted to N.C.O. rank only 18% Grades IV and V had been so promoted.

With the increasing complexity of the soldier's equipment and training there must be a continued need for the development and application of suitable selection techniques. When it is realized that about 5% of the army's recruits in the years under review were unable to profit by ordinary training and were only fit for labouring duties it will be realized how important it is to be able to draft these into necessary and suitable jobs. Most of the selection is based on tests devised and proved by scientists and capable of easy application by trained lay selection officers.

The statistical section of the Report is a mine of information on the causes of non-effectiveness, and the outstanding impression one gets is of the great importance of the minor maladies. The Army Medical Services are to be congratulated on producing under very great difficulties a very valuable and interesting study.

BOOK REVIEWS

Toxicity of Industrial Organic Solvents. By Ethel Browning. I.H.R.B. Report No. 80, revised edition. (Pp. 411. 35*s*.) London : H.M.S.O. 1952.

This edition, like its predecessor published in 1937, is a series of valuable monographs. Dr. Ethel Browning has collected literature on the toxicity to men and animals of 126 solvents and has succeeded in making the narrative very readable. Additions include monographs on substances such as silicones and picoline which have only recently come into common use. The extent of the literature and the dullness of much of it makes her achievement on both scores most notable. The selection has been admirable : the trivial has been omitted but nothing of importance missed. Also, Dr. Browning has drawn on the files of the Home Office and Ministry of Labour for some of her information. The result is a concise and comprehensive narrative. Any monograph might be taken as a model : that on benzol is superb. The preface tells us 15·2 million gallons of it (excluding motor and aviation spirits) were distributed in 1951.

No serious criticism can be offered on the book. A minor improvement would be to place the references immediately after each substance rather than at the end of the chapter where of necessity they accumulate into a formidable list. Some expression of Dr. Browning's views on the literature she reports would be especially valuable.

The book should be of value to all physicians interested in industrial medicine, but if chemical engineers and managers and whoever deal with toxic solvents kept this book on their desk, many hazards might be avoided. A daily lectionary would do much to safeguard the health and life of men exposed to toxic solvents.

The Food and Drug Act 1938 requires that patent medicines must have the formula printed on the label. Admittedly, the formula is often designed to blind the ignorant, and the not-so-ignorant, but at least it is there and can, with patience, be deciphered. Those who have to deal with commercial solvents and paints know how difficult it is to find out what is actually in the product. If the formula is not regarded as secret, it is certainly surrounded in mystery and sometimes it seems that even the manufacturers do not know what they have put into a solvent. If a member of parliament, who had luck of the draw, introduced a Bill to enforce the declaration of the constituents of all solvents and paints, etc., he would do a lot to preserve health in industry. Even so, the study of Dr. Browning's work would still be essential.

T. A. LLOYD DAVIES

The National Health Service. A Guide for Practitioners. Edited by Max Sorsby. (Pp. 267. 12*s*. 6*d*.) Edinburgh : E. & S. Livingstone. 1953.

This is a valuable little book produced for the very modest price of 12s. 6d. It covers the whole range of medical services and all forms of insurance, benefits, compensation, and pensions administered by the State ; it will serve a useful purpose in explaining the complicated, detailed and, at times, almost incomprehensible legal terminology of the various acts, orders, and regulations which form the structure of the scheme. It even goes further and makes a rather dry subject always readable and often interesting and it can be read as a book quite apart from its main function as a work of reference. It is sure to become a textbook for the student reading for the Diploma in Public Health and all interested in state medicine.

The book is, however, addressed to the general practitioner who is a particularly vulnerable victim of the great mass of legislation. He has never the time and rarely the interest to read the acts and their riders in the original, and a readable working guide, which is admirably complete, should be of the greatest service to him.

From the strictly medical aspect there is little of interest to the doctor in industry but the economic side is of importance to him, and furthermore most doctors in industry are also general practitioners.

The book is divided into six sections ; the first is devoted to an historical explanation of the evolution of the Health Service, the second to the doctor-patient relationship showing the rights of each, and the third to the various statutory bodies administering the Service, with separate chapters on the Medical Practices Committee, the Executive Council, the Local Medical Committee, National Insurance, the Local Health Authority, and Hospital Boards. Each is written by an expert in his own field and there is no overlapping of subject matter.

Section 4 deals with the non-statutory bodies : the General Medical Services Committee, the B.M.A., and the Guild of Freedom in Medicine. Section 5 describes the special services, dental, eye, maternity, pharmaceutical, and hospital welfare, and includes an interesting chapter on the work of the coroner.

Section 6 is the only non-factual part of this work and has two chapters on " Some Remediable Deficiencies " and " Looking Forward ". The first of these is written by the editor and few will disagree with Dr. Sorsby's proposals which are sensible and restrained, but the epidemiologist may boggle at the sugges ion of nursing

tuberculosis in general wards, however many cases may gain accidental admission with another disease. Particularly will he find an echo in the hearts of most doctors about getting patients into hospital, especially the aged, and the regrettable fact that the patient can pillory the doctor before the Executive Council but the doctor has no similar redress against the patient. There is much strong feeling about this near relation of the " people's court " of less happily governed countries, and at least the doctor should be able to have equal rights before it.

The last chapter on " Looking Forward " sometimes means looking very far forward, and by no means all doctors will agree with parts of it, but this is an interesting chapter with many valuable suggestions on improving the Health Service. A member of the staff of Yale University Department of Public Health drew the administration of the Health Service on the blackboard and opened his lecture as follows : " Only in England, if anywhere, could such a thing work ". The point is it *does* work fairly well and we should hasten slowly towards a soulless perfection.

J. P. W. HUGHES

Praktische Arbeitsphysiologie. By Gunther Lehmann. (Pp. viii+352 ; 145 illustrations. DM. 29.70.) Stuttgart : Georg Thieme. 1953.

The author is Director of the Max Planck (formerly the Kaiser Wilhelm) Institute for Industrial Physiology at Dortmund, and this book is based mainly on the researches carried out by himself and his colleagues. The book is intended as a practical handbook for doctors working in industry, engineers, and generally for those concerned with the management of labour. It outlines the results of researches in industrial physiology which are capable of practical application in such a form that they can be readily understood by one who is not a trained physiologist.

After some preliminary discussion, there comes a chapter which describes the structure and function of muscle, the phenomena associated with static and dynamic effort, reflexes, and motor coordination.

Then follows a long chapter on the conditions and effects of work. It deals with fatigue and recovery, and the effects of rest pauses and of adaptation. It is remarked that in determining human performance both physiological and psychological factors play their part, and that whatever the physiological capacity for work good performance also depends on the will to work. There are illustrations of the effects of sugar and phosphates, and of various drugs on performance; work-curves are discussed in relation to physiological rhythm; and there is a good section on posture at work.

A further chapter deals with energy production and expenditure. Calory requirements for workers in various occupations are tabulated, and for some occupations the varying rates of energy expenditure during working hours are shown. There is a detailed consideration of the relationship between the maximum effort that can be exerted and the duration of effort.

Members of the Max Planck Institute have made many studies of the energy costs of various types of work, such as shovelling, hammering, and turning cranks, and the data from these are used in a discussion of rational work in which physiological consideration in machine construction are also dealt with.

In a chapter on the working climate the measurement of warmth and the effects of work at low and at high temperatures are examined. The discussion of the effects of high temperature includes a section on radiant heat. Salt excess and salt deficiency are considered, as is also the question of how much and what the worker should drink.

A further chapter deals with the composition of the air and atmospheric pressure with special reference to mining and caisson work ; and another discusses work in relation to vision, noise, and vibration.

A discussion of nutrition and work brings out the dependence of work on adequate nourishment.

Finally, there are two chapters concerned with wages systems and hours of work.

This book is an excellent one and it is well produced.

THOMAS BEDFORD

Some Common Psychosomatic Manifestations. 2nd edit. By J. Barrie Murray. (Pp. XI + 285. 17*s.* 6*d.*) London : Oxford University Press. 1951.

A physician who has taken a special interest in the emotional aspects of various diseases writes this book. " The communication is concerned entirely with the physical expression of the emotions irrespective of the personalities of the patients." He gives extensive accounts of effort syndrome and miner's nystagmus. Indeed the discussion of the literature dealing with these and of the author's personal experience of them occupies two-thirds of the pages. The remainder are devoted to short notes, mainly clinical, on the eye symptoms in thyrotoxicosis, the importance of emotion in precipitating or maintaining skin disease, " rheumatism " which has no obvious organic basis, and dysfunctions of the alimentary tract such as certain forms of colitis, constipation, proctalgia, and nervous dyspepsia.

The author's vocabulary is at times confusing. For instance, the introduction begins with the sentence : " There is little doubt that 60 per cent. of cases seen in a medical out-patient clinic are psychiatric in nature, and if these cases are not entirely psychiatric, they are predominantly so ". It might have been better for the sake of clarity to have restated this sentence in such a way as, " When a physical examination of a patient is supplemented by psychological and social investigations new facts are often revealed which may be of considerable importance for treatment and prevention ". As the sentence stands the figure of 60% is meaningless. Or again, " Recognition of the psychiatric nature of the patient's complaint, either as an entirely psychosomatic condition, or a somatic condition with a psychoneurotic element, is essential." But what is a " condition " and what is an " element " ? One is reminded of the famous medical report which read, " The condition of this man's

stomach condition is in the same condition as it was a month ago".

The main value of the book, apart from its very full description of effort syndrome and miner's nystagmus, is its clinical observations from the psychosomatic point of view. The author emphasizes the frequency of unrecognized depressive states which are missed by the clinician who has concentrated solely on one or other of the various physical symptoms which may accompany them. He mentions the unusually high incidence of a history of urinary infections in cases of backache. (It would be interesting to know if many of these had been given an anaesthetic in the lithotomy position, for a stretched sciatic nerve or a slipped disc is a recognized complication of such circumstances.) He also mentions how microcytic anaemia may be provoked by stress and improved when the stress is removed. He attributes this to the possible diminution of appetite at times of anxiety. But some people during stress actually eat more than usual!

This is a sincere piece of work and the information which it provides will be of interest and value to many.

J. L. HALLIDAY

BOOKS RECEIVED

(Review in a later issue is not precluded by notice here of books recently received.)

Medicine. By Hugh G. Garland and William Phillips, with Foreword by F. A. E. Crew, Vols. I and II. (Pp. 2,146; illustrated. £6 0*s*.) London: Macmillan. 1953.

The Case Against Psychoanalysis. By Andrew Salter. (Pp. 179. 10*s*. 6*d*.) London: Medical Publications Limited. 1953.

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THE APRIL (1953) ISSUE

The April (1953) issue contains the following papers :—

Respirators for Protection Against Mercury Vapour. By V. B. Vouk, Z. Topolnik, and M. Fugaš.

The Action of Flint of Variable Size Injected at Constant Weight and Constant Surface into the Lungs of Rats. By E. J. King, G. P. Mohanty, C. V. Harrison, and G. Nagelschmidt.

Dust Sampling to Simulate the Human Lung. By H. H. Watson.

Pneumoconiosis of Coal Miners in Scotland. By John Black.

A Pilot Investigation into the Occurrence of Pneumoconiosis in Large Power Stations in South Wales. By Idris Davies.

The Expected Frequency of Bladder Tumour in Works Populations. By R. A. M. Case.

Methyloctylbenzenesulphonate: A New Industrial Sensitizing Agent. By C. N. D. Cruickshank and H. Howard-Swaffield.

Psychological Handicap in Relation to Productivity and Occupational Adjustment. By Morris Markowe and L. E. D. Barber.

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 12s. 6d.

ABSTRACTS

(This section of the JOURNAL *is published in collaboration with the two abstracting Journals,* Abstracts of World Medicine, *and* Abstracts of World Surgery, Obstetrics, and Gynaecology, *published by the British Medical Association. The abstracts are divided into the following sections: toxicology; industrial physiology; industrial lung disease; industrial skin diseases; accidents and orthopaedic surgery; industrial ophthalmology; environment; general. Not all sections will necessarily be represented in any one issue)*

INDUSTRIAL TOXICOLOGY

Acrylonitrile: Spectrophotometric Determination, Acute Toxicity, and Mechanism of Action. BRIEGER, H., RIEDERS, F., and HODES, W. A. (1952). *Arch. industr. Hyg. occup. Med.*, **6**, 128.

After a review of the literature dealing with acrylonitrile, its properties and toxicity, and the methods in use for its determination in air, a new spectrophotometric method of estimation whereby very small quantities can be determined (20 to 60 litres for concentrations of 10 to 100 p.p.m.) is described in detail. The air to be tested is drawn at a rate of 1 litre per minute through two gas-washing bottles connected in series, each containing 300 ml. of water and being immersed in an ice bath. The quantity of acrylonitrile dissolved in the water is then estimated spectrophotometrically from the ultraviolet absorption spectrum, a wave length of 210 mμ being chosen. The methods of sampling and of estimation, the details of which are clearly described, were tested against the Kjeldahl (Petersen and Radke) method with satisfactory results. For the detection of acrylonitrile in blood, 1 ml. of blood is diluted tenfold with 0·1 N caustic soda and the solution heated to 30° C. and aerated for 30 minutes in two narrow tubes, each containing 10 ml. of water, which are connected in series and immersed in an ice bath, the aqueous solutions being then examined spectrophotometrically in the same way.

Rats, dogs, and monkeys were each exposed for 7 hours to acrylonitrile vapour in air, the concentration being determined by the above method. No acrylonitrile was found in the blood of these animals, but estimations were made of the haemoglobin and methaemoglobin content, and of the concentration of cyanide in whole blood, erthrocytes, and plasma, and of thiocyanate in whole blood, plasma, and urine. Cyanide was present in high concentration in the blood of dogs exposed to concentrations of acrylonitrile of 100, 75, or 50 p.p.m. (all 6 dogs exposed to 100 p.p.m., and 3 of the 4 exposed to 75 p.p.m. dying), and in the blood of rhesus monkeys exposed to 75 p.p.m. (one of the 3 exposed dying). Only very small amounts were present in the blood of rats exposed to 100 p.p.m. (4 out of 20 dying) and none in that of rats exposed to lower concentrations. Most of the cyanide present in the blood was in the erythrocytes. Cyanmethaemoglobin was found in the blood of all these animals. Thiocyanate was present in very high concentration in the plasma of the rats and in low concentration in the plasma of the dogs, its concentration varying inversely with that of cyanide and with the severity of toxic signs. In the early stages of exposure the venous blood was hyperoxygenated and bright red in consequence of the histotoxic anoxia: later the blood became darkened. The animals severely exposed suffered brain damage characteristic of anoxia, the cortex being most severely affected. Similar changes, but of lesser degree, were present in those animals exposed to lower concentrations and which had shown no toxic symptoms. It is concluded that the toxicity of acrylonitrile is due to the formation of cyanide in the body. The cyanide is further metabolized to thiocyanate, which is excreted in the urine. Emergency treatment with amyl nitrite by inhalation and sodium nitrite and thiosulphate intravenously is recommended in cases of acrylonitrile intoxication.

[This is an important paper.]

M. A. Dobbin Crawford.

Pharmacologic Properties of Toxaphene, a Chlorinated Hydrocarbon Insecticide. COUNCIL ON PHARMACY AND CHEMISTRY, AMERICAN MEDICAL ASSOCIATION (1952). *J. Amer. med. Ass.*, **149**, 1135.

Toxaphene, a chlorinated camphene with the formula $C_{10}H_{10}Cl_8$, is one of the newer insecticides. It is an amber-coloured, waxy solid with a wild, pine-like odour and contains 67 to 69% chlorine. It melts at 70° to 95° C., is insoluble in water but soluble in oils and in the common fat solvents, and is practically non-volatile. It is a slow-acting, residual insecticide and is used in the form of a dust, emulsion, spray, or wettable powder. It has been widely employed for grasshopper control and as a supplement to DDT. It has also been used as a cattle dip, but should not be used for dairy cattle or in dairy cow-houses. It is not safe for household use, nor is it suitable for delousing, in spite of its persistence and its resistance to laundering.

Toxaphene causes a diffuse stimulation of the brain and spinal cord, resulting in generalized tetanoid or clonic convulsions which return at intervals of 3 to 5 minutes and terminate in respiratory failure. In experimental animals salivation and emesis precede the fits, but these symptoms have not been observed in human beings. The lethal oral dose for man has been estimated as being

from 2 to 7 g. Toxaphene can be absorbed through the gastro-intestinal tract, through the respiratory tract, and through the skin. In solution it is readily absorbed ; in the solid form it is absorbed in toxic amounts depending upon the species of animal and the concentration of the powder (dust) used. Toxaphene is approximately four times as acutely toxic as DDT to most animals. It is probably stored in the fat depots of the body, and is believed to be slowly detoxified in the liver (as camphor is known to be) as analysis of the urine has yielded ethereal sulphates and glucuronic acid conjugates of toxaphene. It is excreted also in milk.

When toxaphene has been ingested it is urgently necessary to evacuate the stomach and intestines by means of gastric lavage or induced vomiting, and saline cathartics. Oily cathartics are contraindicated, as they may possibly aid absorption. Early medication for the prevention or control of convulsions is necessary, and for this the barbiturates are effective. If given before the onset of convulsions the slow-acting depressants, such as phenobarbitone sodium, are the drugs of choice ; if convulsions have already started, the quick-acting barbiturates such as pentobarbitone sodium are more effective, and full anaesthetic doses can be given if necessary. If convulsions have started, it is imperative to give sufficient barbiturate quickly, for the longer the convulsions persist the more difficult are they to control.

M. A. Dobbin Crawford.

Accidental Poisoning by Toxaphene. Review of Toxicology and Case Reports. McGee, L. C., Reed, H. L., and Fleming, J. P. (1952). *J. Amer. med. Ass.*, **149**, 1124.

" Toxaphene " (chlorinated camphene), one of the newer insecticides, is a convulsant drug which, having a specific effect upon the central nervous system, provides no warning symptoms such as nausea, colic, or diarrhoea. From 1 to 3 or more hours after the poison has been swallowed, the convulsions suddenly begin and there is loss of consciousness. In this paper 4 cases are reported in detail occurring in young children who had access to the insecticide ; 3 of the children died from asphyxia during a convulsion ; the fourth recovered after receiving large doses of phenobarbitone and curare intramuscularly.

Also reported are two instances of group poisoning which followed the eating of green vegetables which had previously been sprayed with toxaphene. The vegetables had been washed in water and cooked before being eaten ; in one instance they had been boiled for one hour with salt pork, and 3 of the people who partook of this food became convulsed ; all recovered following treatment by gastric lavage or with apomorphine and sedation by phenobarbitone sodium. The published results of animal experiments are quoted. Toxaphene in an oily solution can be absorbed through the skin of rabbits, a dose of 250 mg. per kg. body weight causing death within 24 hours, but there is poor absorption by the skin if the drug is applied in an inert powder. Anaesthesia with barbiturates has protected dogs from the effects of supralethal doses. Where convulsions have already started, pentobarbitone sodium is the drug of choice. No case of industrial poisoning is on record. Toxaphene has been produced and investigated during the past 5 years.

M. A. Dobbin Crawford.

Malignant Nephrosclerosis due to Chronic Industrial Lead Poisoning. Grobdorfer, K. (1952). *Mitt. Ost. SanitVerwalt*, **53**, 247.

That advanced chronic nephritis is now rarely found in lead workers is largely due to the statutory measures adopted for their protection. The 3 patients whose cases are here recorded had each had prolonged industrial exposure to lead, and during the early years medical supervision was quite inadequate. Two of the men were employed in the recovery of lead from the gases evolved from the roasting ovens, hearths, and blast furnaces of a lead works. The fumes were led through pipes 40 cm. (16 in.) in diameter threaded with a high-tension cable whereby the dust, consisting of metallic lead, lead oxide, and lead sulphide, was ionized and deposited on the inner wall of the piping and on the cable itself, to be knocked off later. Exposure was severe. One man had been employed here continuously for 16 years, and the other for 22 years except for an interval of 2 years following an acute attack of lead poisoning. The symptoms of hyperpiesis eventually caused each of these men to consult his doctor, the blood pressure being 240/120 mm. Hg in the one and 250/160 mm. Hg in the other. At this stage their conditions were very similar, with headache, backache, defective vision (due to albuminuric retinitis), slight anaemia (though no stippled cells could be found), and albuminuria, the urine containing a few erythrocytes, leucocytes, and epithelial cells. One man carried on at light work, his working capacity being reduced by 75%, and a year later his condition showed little change. The other had two attacks of epileptiform convulsions and died within a year of diagnosis. At necropsy there was marked hypertrophy of the left ventricle of the heart and the changes typical of an intracapillary glomerulonephritis, many of the glomeruli being completely hyalinized and obliterated, while the arterioles were markedly sclerotic, the vasa afferentia alone escaping this change. It could not be determined whether the primary change had been a glomerulonephritis or a capillary injury due to the toxicity of lead.

The third man, aged 44, had been employed for 25 years at a lead-paint factory on the various processes (which are described) in the production of white lead $2\ PbCO_2\ .\ Pb(OH)_3$), which, although almost insoluble in water, is sufficiently soluble in the body fluids to be toxic. He suffered recurrent attacks of acute lead poisoning in 1927, 1930, and 1934. In 1938 an increase was found in the number of stippled erythrocytes in his blood, and severe hypertension with cardiac insufficiency developed. By December, 1949, his heart was dilated, his joints were swollen, and he had constant albuminuria. He died from uraemia in February, 1950. His death was attributable to failure to recognize that his recurrent attacks of acute intoxication indicated a susceptibility to lead which required his removal from contact with the metal at an early stage.

These three cases emphasize the importance of regular and thorough medical supervision of all lead workers, and of their removal from hazard at the first suspicion of warning symptoms related to the urinary system. The issue may be fatal without the appearance of other classic signs of lead intoxication. *M. A. Dobbin Crawford.*

The Treatment of Lead Poisoning by the Intravenous Administration of Sodium Thiosulphate. SHIELS, D. O. (1952). *Med. J. Aust.*, **1**, 879.

The use of sodium thiousulphate in the treatment of lead poisoning was first reported on by Dennie and McBride (*Arch. Derm. Syph., Chicago*, 1923, **7** (63). Pincus published a short note of his experience in this form of therapy in 1936 (*Med. J. Aust.*, 1936, **1**, 463), and the present author outlines the work done at Mount Isa, Australia, in more detail. The lead-mine at Mount Isa employed about 1,200 men in 1935, and between 1931 and 1936 there were respectively 69, 95, 77, 71, 71, and 71 compensable cases of lead-poisoning each year. All these cases were examined by a medical board, but there was a number of milder cases in addition. The author has selected 18 cases to illustrate the value of sodium thiosulphate in treatment. All the patients received this form of therapy, but some were given calcium to control colic, while one case required morphine.

The effects of treatment were judged clinically by the medical board, who formed the opinion that the improvement under this method of treatment was more rapid than could be accounted for by removal from exposure to lead. The ratio between monocytes plus large lymphocytes and small lymphocytes was used to judge this improvement numerically. Before this treatment was instituted the average ratio for the 18 cases was 1·23, whereas after some days' treatment it rose to 3·22, which approaches the normal value for persons at Mount Isa who are exposed to lead but are without symptoms.

The injections consisted of 30 mg. of sodium thiosulphate in a few ml. of water, given on alternate days. Two or 3 to 12 or more injections were required. *W. K. S. Moore.*

Investigations on the Toxicity of Some Organic Mercury Compounds which are Used as Seed Disinfectants. (In English.) SWENSSON, A. (1952). *Acta med. scand.*, **143**, 365. Bibliography.

The toxicity of the following mercurials, all of which are used as seed disinfectants, has been examined: methyl and ethyl dicyandiamide, methyl mercury chloride, phenyl mercury acetate, and mercuric chloride. The LD50 for a single intraperitoneal injection in mice observed for 7 days was estimated for each drug, the results being 0·39, 0·38, 0·31, 0·26, and 0·14 mg. per kg. body weight respectively. Subcutaneous injection produced severe and widespread necrosis of the skin, while interpretation of the results of repeated intraperitoneal injection was difficult owing to the development of peritonitis. Mice were also exposed to air passed over the mercurials (but since no determinations were made of the vapour concentrations to which the animals were exposed, these experiments only demonstate the order of volatility of the compounds). Determinations of the mercury content of tissues of rabbits after a single intravenous injection of methyl mercury dicyandiamide showed that the concentration in the kidney and liver fell appreciably over a period of 44 days, while that in the brain and muscles fell much more slowly.

W. N. Aldridge.

Further Investigations on Chronic Cadmium Poisoning. A Study on Rabbits with Radioactive Cadmium. FRIBERG, L. (1952). *Arch. industr. Hyg. occup. Med.*, **5**, 30.

In this study 4 rabbits (Group 1) each received a daily dose of cadmium sulphate solution in water on 6 days a week for 10 weeks, the dose being 0·65 mg. of metallic cadmium per kg. body-weight. This contained the radioactive isotope ^{115}Cd with a half-life of 43 days. At the start of the experiment the radioactivity measured about 0·25 mc. per g. of cadmium. The solution was given by subcutaneous injection and the total cadmium given was 40 mg. per kg. Another group of 4 rabbits (Group 2) was similarly treated, but for 4 weeks only; the total cadmium given was 15 mg. per kg.

Little cadmium was found in the urine during the first 6 weeks, but large quantities were excreted by the kidneys during the 7th and 8th weeks, up to 50 or 100 times the normal quantity. This coincided with the appearance in the urine of a protein of low molecular weight. Evidence is given indicating that a part of the cadmium may be bound to this protein. The animals were then killed by bleeding. The blood of the animals in Group 1 contained cadmium to the extent of 0·7 to 1·3 μg. per ml., all of which was in the erythrocytes; none was found in the plasma. Cadmium was found to be present in all organs of the body in both groups of rabbits (precise quantities are given) with accumulations in the liver, kidney, pancreas, and spleen. *M. A. Dobbin Crawford.*

On Hypersensitive [*sic*] **to "Para Group".** (In English.) RAJKA, G. (1952). *Acta allerg., Kbh*, **5**, 11.

para-Phenylenediamine, which is extensively used in the dye industry, is known to be a strong sensitizer, though why compounds in the *para* position are important from the point of view of sensitization is not known. It would seem that sulphonamides and *p*-aminobenzoic esters (for example, procaine), besides being strong sensitizers, will induce mutual sensitivity, and an individual sensitive to one of them will react positively to any of the others. From a study of 23 patients sensitive to the "*para* group" the author suggests that cross reactions can never be predicted, though by studying the occupation and enquiring about the use of procaine, for example, the original sensitizer can often be singled out. This may be important because on it depends to a certain degree the extent of the antigenic cross reactions. In one case 200 mg. of acid yellow or of amaranth, two common azo dyes used in foods, produced a rash in a woman sensitive to *para*phenylenediamine, nylon dye, and other "*para* group" substances. A list of these substances is given in a table. *A. W. Frankland.*

DUST SAMPLING IN THE CONTROL OF COAL MINERS' PNEUMOCONIOSIS

In this number of the *British Journal of Industrial Medicine* we publish a symposium of four papers concerned with determining and maintaining safe concentrations of airborne dust in coal mines. The problem is complex, for dust concentrations continuously vary over wide ranges in time and place, and pneumoconiosis develops asymptomatically over a period measured in years. Since exposure to concentrations of dust that would be highly dangerous for a long period may be quite innocuous for a short period, the concept of a "maximum allowable concentration" is inappropriate, and we have to consider a method of integrating all the concentrations to which a man is exposed over the years.

Should this integration be a simple average of all the momentary concentrations or, as has been often urged, are the higher peaks of concentration disproportionately dangerous so that they should be given special weight, while the troughs of concentration can be ignored as contributing nothing to the risk? Wright (p. 235) argues that the severity of pneumoconiosis is related to the amount of dust retained in the lung, and he supports the "average" hypothesis that "the rate of accumulation of dust in the lung is directly proportional to the concentration of respirable dust in the air that is breathed". The upholders of the opposing "peak" hypothesis claim that high concentrations of dust overwhelm the lungs' protective mechanism so that a higher proportion is retained. It is difficult to see how the concentration of dust could affect the proportion reaching the alveoli where dust must be deposited to be retained in the lung, and there is no reason to suppose that the proportion of this deposited dust entering the lung tissue is greater when the concentration is higher. Even during the most severe experimental exposure, dust is deposited very slowly in individual alveoli and it is all phagocytosed within a few minutes. Wright does not consider the balance between the rate of accumulation in the lung and the rate of removal to hilar lymph nodes. It is conceivable that this secondary cleansing mechanism of the lung may be able to deal with low but not with high rates of accumulation (Rossier, 1953).

Fortunately it may be possible to side-step this debate. If special allowance is to be made for peaks of high concentration, such allowance would be dependent on both their frequency and their height, which Oldham (p. 227) finds are simply related to the average concentration. He reaches the important conclusion that a "lognormal law of constant proportional standard deviation is a general property of underground dust concentrations". The higher the average concentration, the higher and more frequent are the peaks. Thus the average is all that needs to be determined, on both the "average" and the "peak" hypotheses of dust retention, to give a valid index of the hazard.

It is also shown by Oldham that a short-period sampler, such as the thermal precipitator, is a most uneconomical method of estimating average concentrations, for momentary variations are so great that very large numbers of samples are required to provide an accurate result. On both theoretical and practical grounds there is need for a dust-sampling instrument which will obtain integrated samples over long periods of at least a week. To economize in sampling manpower, the instrument should be self-operating. The instrument should, of course, sample particles

only within the respirable size range, but the question of the units in which the concentration should be expressed (number of particles, surface area, etc.) is largely irrelevant, since it has been shown that in the respirable size-range all the relevant physical characteristics of the dust cloud are highly correlated (Bedford and Warner, 1943 ; Wynn and Dawes, 1951 ; Watson, 1953).

If the simple " average " hypothesis is accepted, Roach (p. 224) shows that for any combination of time (years) and concentration (particles/ml.), dust exposure may be expressed by a single index in " particle years " and may then be related to the incidence of pneumoconiosis, estimated radiologically. In this way an " exposure response curve " may be constructed for any group of men exposed to any dust, the position of the curve in relation to the dust axis giving a measure of the potency of the dust, so that two dusts may be compared. From such curves the proportion of men who will develop pneumoconiosis for any exposure may be read, and, taking the fiducial limits of the curve into account, the definition of safe conditions can be approached. Roach provides an example of the method applied to face-workers at a British colliery where estimates of past dust concentrations since 1939 were based on dust surveys done in 1949 and 1952. Men were considered to have pneumoconiosis if they showed radiological category 1 in the new international classification Cochrane, Davies, and Fletcher (1951). Roach rightly emphasizes that these results from one colliery cannot be used to suggest safe dust levels for all coal mines ; moreover the estimates of dust exposure in the past are uncertain and category 1 carries little risk of disability. We require simultaneous dust sampling and radiological surveys at representative collieries in order to get results which will be generally applicable and to compare the hazards of different dusts. Before such results can be used to establish safe dust exposures, we must know the frequency with which massive fibrosis complicates simple pneumoconiosis in different coalfields and acquire more information on the disability and loss of expectation of life attributable to the different stages of the disease. We should then be able to decide what prevalence of radiological abnormalities may be permitted after various periods of work and thus to determine permissible periods of work at different levels of dust concentration.

It is gratifying to know that these problems are being studied both at the M.R.C. Pneumoconiosis Research Unit and in the National Coal Board's Twenty Pit Survey which is now getting under way.

Wright (p. 235) and Long (p. 241) also consider whether " average " sampling techniques, appropriate for determining safe conditions, are also appropriate for the engineer who will have to achieve and maintain these conditions by dust prevention. It is often argued that he needs a short-period sampler to discover the more important sources of dust production so that his preventive measures may be properly directed, but visual inspection is usually quite sufficient for this purpose, with the possible exception of clouds of redispersed dust, as on roadways, which being highly aggregated may contain relatively few particles in the respirable size-range. For control sampling, to ensure that safe dust-levels are being maintained, a long-term automatic sampler is required, as both Wright and Long insist. Some difference of opinion remains as to the right location of the sampler. The " random collier " method (Oldam and Roach, 1952) gives the best measure of the exposure of a group of men, and is clearly correct for dust-disease correlation, but Long argues that it is inefficient for control sampling, which should be done at fixed points where the worst dust conditions prevail to ensure the safety of the men working in such places. He states, but does not demonstrate, that the spatial distribution of dust concentrations is so stable that fixed points can always be chosen to show the highest concentrations. Even if this were so, it must be realized that such samples might lead the engineer to reduce the average exposure, by unnecessary and costly dust suppression, well below that required to protect the majority of men. It might be more economical to determine the overall average exposure of the men by a roving sampler, and to rely upon periodic *x*-ray examinations to protect

those men who happen to work in places where the average concentration is persistently exceeded.

We must not assume that present methods of dust suppression, such as wet drilling and cutting, water infusion and spraying, and good ventilation, will suffice to provide acceptable dust concentrations. Roach's investigations revealed average concentrations at one colliery greatly in excess of those at present approved, although every endeavour had apparently been made to suppress the dust in recent years. In coal mines and elsewhere research must be intensified in a field about which we hear too little, namely the development of new techniques for preventing the formation of dust and for its suppression.

Our symposium provides an important contribution to the clear thinking required in planning environmental research into pneumoconiosis. Some of its lessons might well be applied to the problem of industrial pulmonary disease in other spheres.

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Brit. J. industr. Med., 1953, **10**, 220.

A METHOD OF RELATING THE INCIDENCE OF PNEUMOCONIOSIS TO AIRBORNE DUST EXPOSURE

BY

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(RECEIVED FOR PUBLICATION SEPTEMBER 1, 1953)

One of the tasks of the Pneumoconiosis Research Unit has been to try to relate the incidence of pneumoconiosis to the environment in which it has developed. In surveys in coal-mines, the incidence of pneumoconiosis among the miners has been measured by *x*-ray examinations; in addition, detailed industrial histories and measurements of the miners' dust exposure have been collected. In this paper we discuss the method of inter-relating the information obtained.

Historical Background

The first important combined investigation of airborne dust conditions and incidence of pneumoconiosis was carried out by the U.S. Public Health Service in three anthracite mines in Pennsylvania (Bloomfield, Dallavalle, Jones, Dreessen, Brundage, and Britten, 1935). The diagnosis of pneumoconiosis was based upon a radiograph of the chest and clinical examination, and airborne dust concentrations were measured with the Greenburg-Smith impinger. The dust samples were taken in "typical" places selected beforehand, and in each place samples were obtained representative of each operation. These results were combined with time studies in order to estimate the average dust exposure in each occupation. The authors considered that the dust determinations were representative of the conditions which had existed in the mines for at least 30 years so that by reference to each man's industrial history it was possible to calculate the average concentration to which he had been exposed.

When the incidence and severity of the disease in these anthracite mines were compared with the average dust concentration and the period of service, it was clear that length of service and dust concentration were both important factors in the development of the disease. The fact that some men developed the disease before others was attributed to their having been exposed to dust for longer periods and at higher average concentrations than their fellow-workers.

This investigation was followed by a similar study at 10 pottery plants in West Virginia (Flinn, Dreessen, Edwards, Riley, Bloomfield, Sayers, Cadden, and Rothman, 1939). The diagnosis was again based upon a clinical and *x*-ray examination and, as before, the average concentration over his working life, weighted by period of exposure in each occupation, was calculated for each man. In order to exclude the effect of employment in other dusty industries which might have contributed to the development of the disease, the worker was excluded from the final analysis if he had been employed for more than five years as a coal-loader, or more than three years as a quarry-man. The results were then grouped by years of service in the industry and concentration of dust, and again it was found that the incidence and severity of the pneumoconiosis was highest in the men with the highest concentrations and with the longest periods of service to their credit.

A study in which similar precautions were taken was carried out among the mica and pegmatite workers in North Carolina (Dreessen, DallaValle, Edwards, Sayers, Easom, and Trice, 1940). The increased incidence among men exposed to the higher average concentrations and greatest periods of service was again observed. Standard methods of curve fitting to yield more refined descriptions of the data were considered but rejected because of all the men who entered the industry only the survivors had been studied. Obviously men with silicosis are more likely to leave their work than their fellows who are not affected, since, at least in advanced cases, they are often disabled by the disease.

In surveys of soft coal miners and non-ferrous

metal miners in Utah, Flinn, Seifert, Brinton, Jones, and Franks (1941) and Dreessen, Page, Hough, Trasko, Jones, and Franks (1942) used a more stringent rejection of records of men with experience in other dusty trades. Records of men who had worked for more than two years in any other dusty trade were excluded. The highest incidence was again among men who had worked in the highest concentrations for the greatest length of time, but again the analysis was carried no further.

Dreessen, DallaValle, Edwards, Miller, Sayers, Easom, and Trice (1938), in a study of the asbestos industry, compared the incidence of pulmonary abnormalities with the total dust exposure of the men, combining average concentration with the duration of exposure. They found that the incidence of a number of symptoms and physical signs as well as the appearance of " ground-glass " lung-field markings in the radiographs was related to the total dust exposure, but they considered that the *x*-ray examination was the most direct means then available for detecting the primary effect of inhaled asbestos dust and the diagnosis of asbestosis rested largely on its evidence.

On the basis of the general relationships between incidence, dust concentration, and length of service safe limits of dust concentrations were suggested for each of these investigations. It should be pointed out that such values of concentration refer to the whole period of a man's mining life and consequently are as much influenced by the relative proportions of time spent in the different occupations as by the average level of dustiness in any one of them.

In the investigations of Hart and Aslett (1942) and Bedford and Warner (1943) in coal-mines in South Wales, comparison was limited to one particular occupation, that of coal-getting, in a number of different mines. Further, when relating the environmental conditions to the medical data a distinction was made between the abnormalities observed in the radiographs and the clinical findings. The radiographs were taken to indicate the presence of the pulmonary condition, whereas the clinical findings were regarded as indicating the disability and constitutional effect produced by that condition. Men were used for analysis who were colliers or assistant colliers at the time of examination or had been within the previous years ; who had spent at least 90% of their total employment at the colliery under examination ; who had spent less than one year as hard-heading workers, less than five years in other underground occupations, less than five years on surface screens, and had never been firemen or shotsmen.

For comparison with the average concentration in the different coal-mines an attempt was made to express the incidence of *x*-ray abnormalities by a single figure which took account of the effect of increasing incidence with years of service. The men were divided into three groups ; those with less than 10 years service, those with 10–20 years service, and those with more than 20 years service. The incidence rate for each of these groups was calculated for eight anthracite collieries taken as a whole. These rates were then applied to each individual colliery and service group, thus giving a figure for " expected " incidence. The ratio between the incidence measured and this expected incidence represented the incidence at that pit relative to the whole anthracite group.

Representative samples of the airborne dust conditions were obtained with the thermal precipitator on the coal-faces. Because of changes that had occurred in the mining conditions over previous years they were only of limited value, but the information was sufficient to indicate a higher incidence in the collieries with the highest dust levels and tentative standards of dustiness were proposed for use as targets at which to aim in controlling dust.

Recent Developments

The Nature of Simple Pneumoconiosis.—Following up the work of Hart and Aslett the Pneumoconiosis Research Unit have continued the study of the radiological appearances of pneumoconiosis.

Pneumoconiosis is now separated into two distinct forms, simple and complicated. Radiographs of simple pneumoconiosis of coal-workers show multiple opacities which appear and progress in association with dust exposure but do not appear or progress as such in its absence (Davies, Fletcher, Mann, and Stewart, 1949). The appearance of these multiple opacities is thus a specific response to exposure to dust and they correspond in general to the foci of dust accumulation in the lungs and the associated tissue reaction (Gough, 1947). With increasing exposure to dust there is a continuous increase in their number and size. Thus the changes in the lung due to the dust deposited there are reflected in the extent or profusion of the opacities in the radiograph.

The radiographs are classified into four categories : 0 (normal), 1, 2, and 3 which roughly correspond to the increasing profusion of the opacities (Cochrane, Davies, and Fletcher, 1951). As the severity of a man's pneumoconiosis increases, radiographs taken at intervals will be classified as category 0, 1, 2, and 3.

All men whose radiographs are classified as lying either in category 1, 2, or 3 are said to have simple pneumoconiosis. Men differ one from another in their rate of working and possibly in the way their lungs deal with dust, so that they may differ in the dust exposure necessary for the appearance of simple pneumoconiosis. However, errors in assessing total dust exposure and in reading the films will have an apparently similar effect. For instance, men whose exposure has been underestimated will appear to be unduly susceptible to pneumoconiosis, while those whose radiological pneumoconiosis has been underestimated will appear to be unusually resistant. Thus the variation in the dust exposure apparently required to produce a particular stage of pneumoconiosis is due to four factors ; two are dependent on the man, and can be considered true variation in susceptibility, and two result from errors of measurement of dust exposure and stage of disease. Each of these last two can be further subdivided : errors of measurement of dust exposure may be due both to errors in dust sampling and also to errors in history taking ; errors in *x*-ray diagnosis may be due to inaccurate and inconsistent readings or to technical defects in taking the radiographs (Fletcher and Oldham, 1949).

Index of Dust Exposure.—A single figure to express dust exposure may be obtained in particle years. This combines the duration of exposure with the concentration of respirable dust and is defined as the product of the two. Dust exposure expressed in this form may be expected to be related to the amount of dust in a man's lungs (Wright, 1953). If a worker's environment has been unchanged for all practical purposes during his period of employment it is easy to calculate, but there must be few dusty industries where the environmental conditions have remained unchanged for as much as 30 years ; even in the same occupation, the dust levels to which a worker has been exposed over his working life have usually varied from year to year, and few workers stay in one job all the time. If a man has thus worked in different concentrations from one year to another, the sum of each year's dust exposure is the measure of his total dust exposure. An example of the calculation of the total dust exposure of a coal miner is given in Table 1. This figure, divided by the total years of employment, gives the average dust concentration to which he has been exposed.

TABLE 1
EXAMPLE OF METHOD USED TO CALCULATE A WORKER'S TOTAL DUST EXPOSURE

Year	Occupation	Average dust concentration (particles/ml.)
1939	Asst. collier	1,750
1940	" "	1,800
1941	" " "	1,850
1942	" "	1,900
1943	Collier	1,950
1944	"	2,000
1945	"	2,100
1946	Cutter-man	2,550
1947	" "	1,500
1948	" "	850
		Total 18,250

Total dust exposure = 18,250 particle-years per ml.
Average dust concentration = $\frac{18,250}{10}$ = 1,825 particles/ml.

The Exposure/Response Curve.—In Fig. 1 E is the total dust exposure necessary to produce simple pneumoconiosis Category 1. If all men were identical and there were no errors of measurement, then all

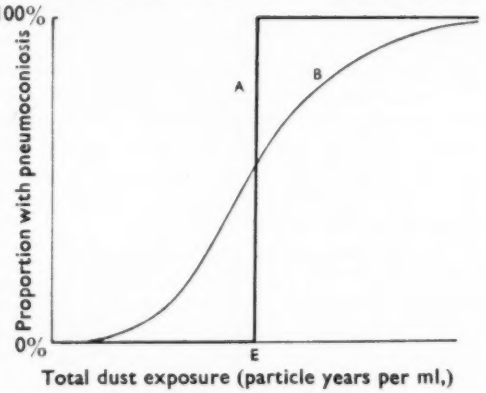

FIG. 1.—Exposure-response curves.

those men with a total dust exposure greater than E would have simple pneumoconiosis and all those with a total dust exposure less than E would not have it ; the response curve would then be Z shaped (A). The effect of variations between the individuals and errors in the measurements is to produce a sigmoid curve (B), which tends towards 0% and 100% at very low and very high exposures respectively, according to the distribution of tolerances in the population and the magnitude of the errors. This curve, which relates the proportion of men found with pneumoconiosis to their dust exposure, is called an "exposure-response" curve. Its slope is a measure of the total amount of variation. It must be emphasized that in practice it is not possible to distinguish variations from man to man from variations due to errors in measurement of dust exposure or category of radiograph.

The construction of an exposure-response curve and its practical use will be shown by an example from data obtained at a colliery in England. We must emphasize that in what follows we do not

mean to imply that the results from the study of one mine should be used to lay down safe levels of dustiness for all collieries. Clearly this would be unjustified on such limited evidence. We give it to show a method of analysis which may be fruitful when applied to a much larger and more varied mass of information such as will be collected in the course of surveys now starting in a representative sample of pits throughout the country.

The investigation was concerned primarily with the coal-getters and their assistants and consisted of two surveys, one in 1949 and one in 1952. In each survey radiographs were taken of all the men, and an airborne dust survey was made of all the coal-faces during the filling shift.

Since about 1915 only one seam had been worked at this colliery and in the period 1939–1952 not only were the workings confined to one seam but also the method of working remained unchanged. The colliery is divided into two main production districts, which we will call " A " district and " B " district. Dust samples, 1,041 in all, were taken with the thermal precipitator over a total of 12 weeks. During the survey in 1949 sampling was done mainly at positions half way along the faces and in 1952 mainly in the working places of coal-getters chosen at random from the whole population, so as to give a fair cross-section of the colliery. The average concentration to which the men were exposed was measured by sampling during the period they were working at the coal-face each day (about 5 hrs. 40 mins.) The summarized results, expressed as average number of particles per millilitre lying between the sizes 0·5 and 5 microns mean projected diameter, are presented in Table 2.

TABLE 2

RESULTS OF AIRBORNE DUST SURVEYS

Year	Population	Average Concentration (particles/ml. 0·5–5 microns diameter)
1949	Colliers in " A " district	1,750
	Colliers in " B " district	2,400
	Whole population	2,400*
1952	Colliers in " A " district	1,050
	Colliers in " B " district	3,100
	Whole population	2,950*

* Expressed to the nearest 50.

Since 1939, so far as could be ascertained from the colliery officials and records, there had been a steady increase in ventilation through the pit and a steady increase in average length of face worked. The conditions as regards length of face, ventilation, output, and position of the loader points in the " A " faces in 1949, were similar to the conditions which held in the pit as a whole in 1939. It was thus possible to make a rough estimate of the average levels of dustiness throughout the period 1939 to 1952. These estimates, obtained by simple interpolation, are given in Table 3.

TABLE 3

ESTIMATES OF AIRBORNE DUST LEVELS 1939–1952

Year	Average Concentration (particles/ml. 0·5–5 microns)		
	"A" Colliers	" B " Colliers	Whole Population
*1952	1,050	3,090	2,950
1951	1,300	2,850	2,750
1950	1,500	2,650	2,600
*1949	1,750	2,400	2,400
1948	1,750	2,350	2,350
1947	1,750	2,300	2,300
1946	1,750	2,250	2,250
1945	1,750	2,150	2,150
1944	1,750	2,100	2,100
1943	1,750	2,050	2,050
1942	1,750	1,950	1,950
1941	1,750	1,900	1,900
1940	1,750	1,850	1,850
1939	1,750	1,750	1,750

* Survey results

In the course of the surveys, industrial histories were obtained from all the coal miners when they were radiographed and included a note of the districts where each man worked, as far as he could remember. From these industrial histories a list was prepared of the men who had been working on the coal-face during the coal-getting shift at some time in the period 1939 to 1952, and from this list were selected those men whose industrial histories showed that they had been exposed to a negligible risk from dust at all other times. These were mostly men who had joined the colliery in the period under study.

The actual criteria used were that the men had worked on the coal-face at that pit within the period 1939–1952 and in addition had (*a*) worked for less than three months as a hard header, (*b*) worked for less than six months as a repairer, ripper, or screen worker or less than five years in any other underground mining occupation, if they had worked for less than five years on the face, (*c*) worked for less than two years as a repairer, ripper, or screen worker or less than 10 years in any other underground mining occupation, if they had worked for more than five years on the face, (*d*) worked on the face only in the period 1939–1952.

The industrial histories detailed the actual years and districts in which the men worked at the colliery, and from the data in Table 3 the average concentration over that period could be calculated for each man. The product of this average concentration and the number of years involved was the estimated total dust exposure of that man expressed in particle-years. Each man worked

approximately 101 hours per month in these dust conditions.

As we have seen, the results from surveys of the incidence of pneumoconiosis may be biased since men with the disease are likely to leave their jobs to obtain lighter work. However, none of these coal-getters had a radiograph as high as Category 3 and none was over the age of 40. Thus they are unlikely to have been affected materially, since men as young as this are not seriously disabled even with quite advanced simple pneumoconiosis (Cochrane, Fletcher, Gilson, and Hugh-Jones, 1951).

The proportion of men with simple pneumoconiosis is given by the proportion of men with radiographs classified as simple pneumoconiosis Category 1 or 2. The appropriate exposure-response curve is given by the regression of response, measured by the proportion of men with simple pneumoconiosis, on the total dust exposure. This is a particular case of regression, identical with that of a biological assay, in which the position of the line indicates the potency of the material and the slope of the line is a measure of variation in individual tolerance and errors of measurement (see for example, Finney, 1952).

TABLE 4
RESPONSE TO DUST EXPOSURE

Total Dust Exposure in Particle Years	No. of Men with Category of Radiograph		Proportion with Simple Pneumoconiosis (%)
	0	1 or 2	
0–3,990	60	0	0
4,000–7,990	24	1	4
8,000–11,990	31	5	14
12,000–23,990	10	9	47
24,000–31,990	0	4	100

The regression of the proportion with simple pneumoconiosis on total dust exposure has been calculated to fit the original data, of which a summary appears in Table 4. Probit and logarithmic transformations were used. The regression line and its 95% fiducial limits is shown in Fig. 2.

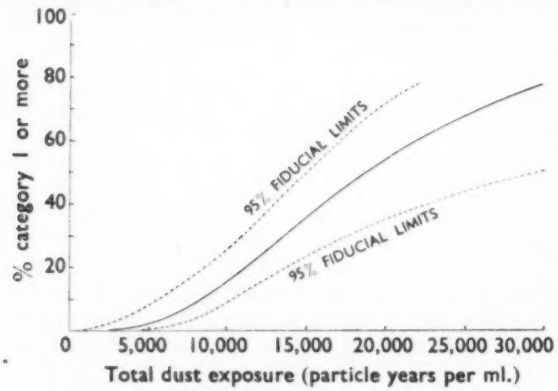

FIG. 2.—An example of the response to dust exposure.

The Prevention of Pneumoconiosis

An exposure-response curve of this kind provides as estimate of the risk of developing pneumoconiosis in terms of the total dust exposure. Although not sufficient in itself, it is an essential piece of information for the establishment of standards of air cleanliness.

For all practical purposes, as long as there is dust there will be some pneumoconiosis, and it is first necessary to consider just how much or how little pneumoconiosis can be tolerated in the colliery. This will depend not only on the number of men involved but also the extent to which their health is affected by pneumoconiosis. This in turn will depend to a large extent on the age of the man and the type of job he does as well as on the stage of disease as represented in the radiograph (Hugh-Jones and Fletcher, 1951). Men with simple pneumoconiosis are seldom disabled by it, but when they have reached the stage corresponding to a Category 2 radiograph they stand a risk of developing progressive massive fibrosis superimposed upon the simple pneumoconiosis, and the combination of the two, called complicated pneumoconiosis, is definitely disabling (Cochrane and others, 1951). Other factors which may have to be taken into consideration are the cost of compensation, dust suppression, dust measurement, and radiological examination, and, in a colliery short of man power, the effect of pneumoconiosis on recruitment as well as on loss of men.

Since the risk of developing pneumoconiosis depends upon the total dust exposure it may be reduced either by reducing the concentration of dust or by limiting the total period of exposure to dust. To take a purely hypothetical case, let us suppose that after due consideration of all the medical, social, environmental, and financial issues, it was decided to ensure that any collier who worked on the coal-face for all his working life should stand less than a 25% chance of developing a Category 1 radiograph, that is the earliest detectable sign of dust in the lungs. The risk of developing a Category 2 radiograph would, of course, be very much smaller than this and the risk of developing the disabling complicated pneumoconiosis would be smaller still. Applying the exposure-response curve it will be seen from Fig. 2 that for this example it would be necessary that the man's total dust exposure amounted to less than 12,500 particle-years. That is, for a working life of 50 years, an average concentration of particles 0·5 – 5μ diameter

of 250 per ml. It follows that it would then be necessary to suppress the dust to such an extent that the mean concentration for the coal-getters, over the period they worked on the face, was reduced to less than this. The less accurate the sampling instruments used to verify this and the more variable the environment, the greater the factor of safety that would be required to ensure that no individual stood a serious risk of achieving a dangerously high total dust exposure.

An alternative to dust suppression or even a substitute for it is to limit the total period of exposure. This may be done either by advising individuals with early signs of pneumoconiosis to obtain less dusty jobs or, more generally, by limiting the period for which a man can work in a dusty job. The use of periodic radiological examinations to aid dust suppression in its object of preventing pneumoconiosis has been suggested by other workers (Cochrane and others, 1951). By instituting examinations every two or three years both the management and individual workers may be given ample warning of working conditions liable to give rise to serious pneumoconiosis, with the additional advantage of detecting the susceptible individual, if he exists.

The other method, of limiting the period for which men can work in a particularly dusty job, might be used in coal-mines by simply having an upper age limit for coal-getting. Again, to take an illustrative example, if the upper age limit were placed at, say 45, then for the same risk as above at this colliery an average concentration of 400 particles per ml. could be permitted. This assumes that these men would then work for no more than 30 years as coal-getters, the rest of their working lives being spent in other, relatively non-dusty occupations.

It should be remembered that in fact very few colliers spend all their working lives on the coal-face. For example, in surveys in eight different collieries it was found that of all the men working underground less than one in a hundred had been working continuously as coal-getters for more than 10 years. In determining the overall risk at a colliery the habits of the average collier have to be considered, but the habits of the individual colliers must be borne in mind in determining the possible risk to the exceptional case.

The Comparison of Different Dusts

Another use of exposure-response curves is for the comparison of the effect on men of different airborne dusts. The first essential is for standardized techniques for taking and classifying the radiographs as well as for sampling procedures and evaluation of the samples. Only when this has been achieved can statistical tests be legitimately applied to examine the significance of differences in response to exposure.

The problems in achieving consistent readings of radiographs have been studied by Fletcher and Oldham (1949, 1951). They found that the highest consistency was obtained in consultative readings in which two or more observers read the films together and discussed each film until they reached agreement. This procedure was recommended for routine work. They also suggested that standard films, exemplifying the limits of the categories, should be used for side-by-side comparison with the films to be classified. They noted that standard films, when properly used, might result in increased accuracy of radiological diagnosis with an experienced observer, but their chief value was to enable the wholly inexperienced observer to use a radiographic classification with an accuracy approaching that of more experienced observers.

The difficulties of obtaining adequately representative air-borne dust samples have been discussed by Oldham and Roach (1952) and the sampling procedure recommended there, called "random colliers", has been found, in practice, to be simple and efficient. In this method members of the population are chosen at random, and dust samples are taken in their working places; so far as possible a different man's working place is chosen for each sample.

As we have noted, the intensity of dust production is usually changing continually, as a result of changes in ventilation, colliery layout, and methods of mining, and it is exceptional for environmental conditions to remain the same for several years on end. It is therefore usually necessary to survey the population repeatedly over a number of years, in which case the survey is confined to men joining the population who have no previous history of dust exposure. These will be mostly new entrants to the industry, straight from school.

The sampling may be confined either to one occupational group such as the coal-getters or the rippers, or, for more general investigations, it may involve all the occupations underground and in the surface works. In either case the sampling is carried out systematically through the population studied by allotting the samples according to a random principle which ensures that the probability that a man's environment will be sampled remains, as is necessary, proportional to his time at risk. Each man's environment will be sampled repeatedly at an average interval dependent upon the number

of men in the population, the number of sampling instruments available and the period covered by each sample. With a constant labour turnover the number in the population studied will grow steadily in size as new entrants join the colliery.

The results from surveys concerning two kinds of dust are then compared in the form of the exposure-response curves discussed previously. A significant difference in the positions of the two curves will suggest a real difference in response to exposure in the two environments, and the relative potencies of the two dusts are expressed in the form of the total dust exposures to produce a specified response. This procedure is again identical with that of the biological assay in which the relative potencies of different drugs are expressed in the form of the ratio of doses to produce a particular response (Finney, 1952). The differences in the potency may then be related to compositional or other differences in the dusts.

Summary

In relating the incidence of pulmonary abnormalities to dust exposure it has been customary to compare the incidence with the concentration of dust in groups of men whose duration of exposure was similar. An alternative procedure is to allow for differences in duration of exposure by comparing incidence with dust exposure expressed as the product of concentration and time of exposure, as this may be expected to be related to the amount of dust retained in the lungs.

An example is taken of the relation between dust exposure and the incidence of simple pneumoconiosis in coal miners. The apparent variation in dust exposure necessary to develop pneumoconiosis as indicated by radiographs is due to a combination of errors in measuring the dust exposure, errors in reading the films, and variations in individual susceptibility.

The appropriate analysis is identical with that used in biological assay. Probit and logarithmic transformation may be used to enable a linear regression of incidence rate on dust exposure to be calculated. This relationship is called an exposure-response curve and gives a measure of the risk of developing pneumoconiosis for a given dust exposure, a measure needed for the establishment of standards of air cleanliness. A decision must first be taken on the maximum risk that can be tolerated and the dust exposure is reduced below the level corresponding to this risk. This may be done either by dust suppression or by limiting the period of exposure.

Exposure-response curves may also be used for comparing different airborne dusts, provided standardized techniques for the survey work are adopted.

It is a pleasure to acknowledge the splendid cooperation of the management and employees at the collieries where the investigations have been carried out. Thanks are due also to the field survey teams who collected the information contained in this report, to all my colleagues who helped in the preparation of this paper, and in particular to Mr. P. D. Oldham who was responsible for the statistical analysis of the results.

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THE NATURE OF THE VARIABILITY OF DUST CONCENTRATIONS AT THE COAL FACE

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It is well known that dust conditions in a coal-mine vary from place to place and from time to time. Watson (1949) pointed out that even at one position on a long-wall face the concentration fluctuates wildly from minute to minute and varies even more from day to day, while the two halves of a double-unit face might differ considerably. Bedford and Warner (1943), when considering the concentration of dust in different mining operations, also noted that there was great variation in the individual dust counts and in addition large variations from mine to mine, so much so that it was not practicable to estimate with any reasonable accuracy an average dust concentration for each mining operation. Other difficulties which this variation causes in dust sampling work have been emphasized by several writers, and Oldham and Roach (1952) have pointed out that it must be given due consideration in designing a sampling scheme which is efficient in terms of the effort needed to obtain a specified amount of information. Fortunately it appears that momentary variation is of little importance in the aetiology of pneumoconiosis. The arguments of Wright (1953) and Long (1953) show that an estimate of average dustiness and the period during which it operates is all that is required, an estimate which could most economically be obtained by means of automatic, long-term sampling instruments. However, so long as short-term, intermittent sampling instruments continue to be used, the effect of this variation must be considered before deductions about average dust conditions may safely be drawn. Equally, it must be allowed for in interpreting the records of past dust conditions. Accordingly, this paper will present some of the evidence that we possess at this Unit of its nature and magnitude, and will draw some practical conclusions.

In the past six years extensive sampling with the thermal precipitator has been carried out by teams from this Unit. The number of samples obtained (some 8,000) is large, although already eclipsed by the number taken by the National Coal Board's sampling teams, which are making ever-increasing use of the thermal precipitator, an accurate though inconvenient and short-term dust-sampling instrument. However, the samples obtained by this Unit have been concentrated at a relatively small number of mines, so that the number of samples representing each different environment is large. Mines with a big range of average concentrations were well represented. In consequence our data are particularly suited to the detection of any consistent patterns in the variation of concentration, such as might be obscured in data covering a less extensive range in less detail.

Few of the surveys we have carried out at this Unit have continued for more than two or three weeks, and it is clear that a statistical treatment of variation of concentration from day to day could not be satisfactory without a long series of daily samples. There are many factors determining the average level of dust conditions during a shift, some of them (such as the width of the workings from face to goaf) clearly likely to cause changes of a cyclic nature, others (the progress of a dust suppression programme, a change in the nature of the coal seam or surrounding strata) inducing more or less steady trends, while a large number will operate in an apparently random manner. Understanding of the effects of such factors will most readily be achieved by analysis of the results of routine dust sampling over long periods of time, provided that such sampling is carried out in accordance with sound statistical principles. This paper will be concerned only with the variation of concentrations about the average level during particular shifts at particular coal faces.

Material

For the most part, our thermal precipitator sampling has been carried out at one or two fixed positions on long-wall faces, in particular at a position about 5 yards from the return end. Samples were also taken half way along the face, and occasionally at the intake end or in intermediate positions. Since the development of the " random collier " system of sampling (Oldham and Roach, 1952) samples have been taken at the working place of randomly chosen colliers, and thus, on the average, have been evenly distributed at all points of different faces. In earlier years the samples were taken systematically at regular intervals throughout the shift, though excluding the " snap " or mid-shift break. Subsequently, and always when the random-collier technique was in use, samples were taken at times chosen beforehand by means of random sampling numbers. In this case samples were taken during snap time if by chance the randomly chosen moment fell therein, but they have been excluded from this discussion. (It may be remarked that few samples taken during snap-time by this Unit have ever produced a countable deposit on the thermal precipitator cover-glasses ; the concentrations in fact were almost always well below 100 particles/ml.) The data therefore concern the period during which work of any kind may be proceeding on the face, and exclude all regular periods of inactivity. The duration of each sample has been standardized of recent years at three minutes (equivalent to a 20 ml. volume of air), but originally ten-minute samples were occasionally taken.

Results

In view of this diversity of procedure it is surprising that the variation of samples about the average for the shift is found to show high consistency and to be almost perfectly proportional to the value of the average. In Fig. 1 the samples obtained during approximately one in 10 of all the shifts sampled at any time by this Unit have been plotted, each at a position corresponding to the average for the shift. The concentrations are expressed as the number of particles between 0·5 and 5·0 microns per ml. of sampled air. The choice of shifts was made on a random basis, but with the intention of covering the whole range of mean concentrations more or less evenly. Accordingly results were taken from the Unit records in serial order, sets with means falling at a concentration already covered being rejected, until the requisite coverage was achieved. Samples from eight different collieries are included.

The scales of Fig. 1 are both logarithmic, so that the consistent width of the scatter of samples over the whole range of averages represents in fact a constancy of proportional variation. The majority of samples fall within a range of 30 to 250% of the shift mean.

The appearance of such proportional variation is characteristic of samples drawn from a population (in the statistical sense) which is of lognormal form. That is, the relative frequency of the logarithms of individual levels of dust concentration appears to be governed by the Normal law. So far as we are aware, this observation has not been previously made. It has been the custom in this Unit for some years to make a logarithmic transformation of dust-sampling results before making statistical tests of significance. The justification for this lay in the obvious increase of variability with intensity of concentration, which was likely to have invalidated the customary assumptions made about the form of sampling distributions. The transformation was observed to render the variability much more stable, but was thought to be merely a convenient device for this purpose. It now appears that not only are the logarithms of concentrations within a shift distributed quite closely in accordance with the Normal law, but that the shape of the Normal curve, determined by its standard deviation, is almost the same in a variety of different faces in different collieries.

It is, therefore, of great interest to estimate the standard deviation of this Normal distribution, for it appears that this parameter will be so nearly constant as to enable us to estimate with its aid the precision to be expected from any set of samples taken within a shift. Moreover, with a knowledge of the form of the distribution of concentrations within a shift, it will be easy to estimate, from the value of the mean concentration, or the total dust exposure measured by an automatic sampler, any other feature of the dust conditions. For example, those who believe that high concentrations are disproportionately dangerous compared with low or average concentrations may wish to test their hypothesis by relating the appearance of pneumoconiosis to the frequency of concentrations above some specified level, a test which, without a knowledge of the relative frequency of high and average concentrations, would require a special sampling technique. As Long (1953) suggests, estimation of the average alone would be quite sufficient.

Analysis

In Fig. 1 samples obtained by the random-collier procedure are marked by crosses. It will be seen that they are fairly representative, except at low

concentrations, of the complete set of results, and statistics calculated from them alone should adequately cover the complete data.

Three such surveys have been made by the Unit up to the present, two at one South Wales pit and one at a pit in England. The distribution of samples within a single shift (that is, within the stint of one random collier) is very similar in each survey. The standard deviations of these distributions are shown in Table 1, the units being logarithms to base 10 of the concentrations in particles/ml.

These standard deviations are very similar, but by means of a test due to Bartlett (1937) it can in fact be shown that the three estimates differ more than would be expected by chance alone. Nonetheless, the differences are small and the pooled estimate, 0·2203, given in the fourth line of the table should adequately represent all three sets. The histogram in Fig. 2 was obtained by pooling the three sets of data and plotting the frequency of different deviations of individual samples from the shift mean, on a logarithmic scale. The normal

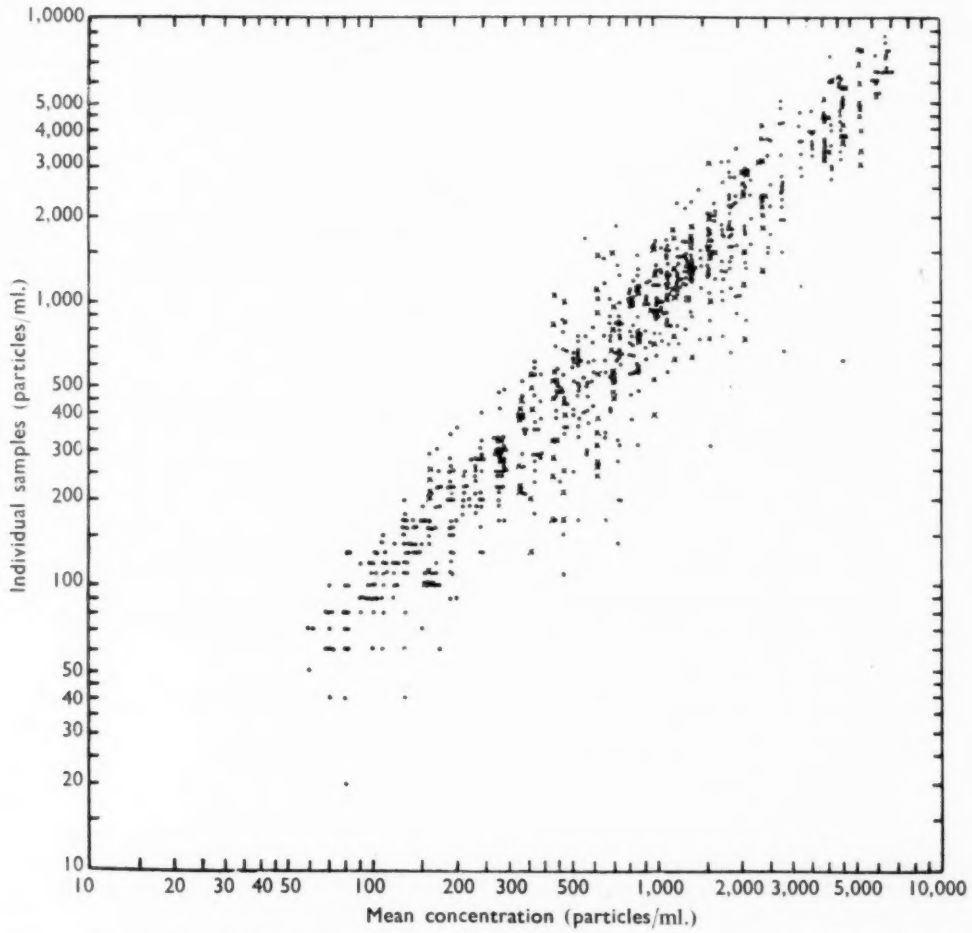

FIG. 1.—The relationship between individual samples and the estimated mean concentration of the shift on which they were obtained.

TABLE 1
ANALYSIS OF THE VARIATION OF CONCENTRATIONS WITHIN A SHIFT OBSERVED IN THREE RANDOM-COLLIER SURVEYS

Survey	Sum of Squared Deviations from Shift Mean	Degrees of Freedom	Variance	Standard Deviation
A	11·990458	303	0·039572	0·1989
B	16·604184	270	0·061497	0·2480
B	9·059755	203	0·044629	0·2113
Pooled	37·654397	776	0·048524	0·2203

The units are logarithms to base 10 of concentrations in particles/ml.

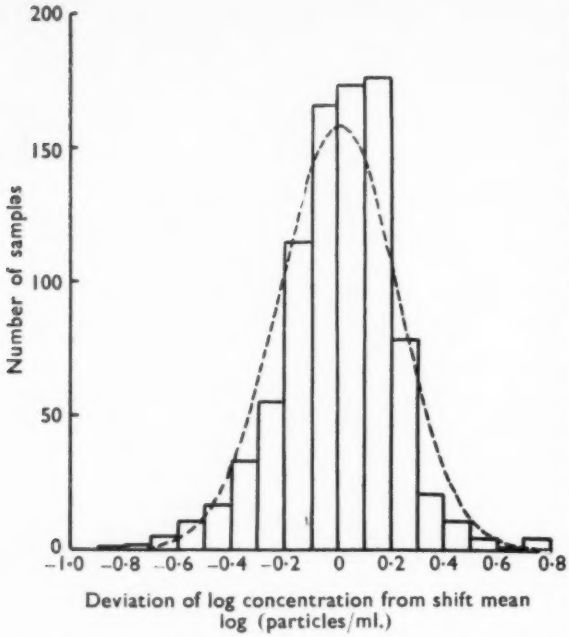

FIG. 2.—Distribution of deviations of 779 transformed samples from their shift means, with the Normal curve of equal area and standard deviation 0·2203.

curve of standard deviation 0·2203 and of equal area is also shown. The fit is fair, but evidently the logarithmic transformation somewhat over-corrects the skewness of the original data, which are also more closely concentrated around their mean than is the Normal curve*. In the normal curve, 5% or 43·7 results should fall outside the limits −0·432 to 0·432. In fact, 44 are found outside these limits, though unevenly placed, 15 on the positive side, 29 on the negative.

Figure 3 shows the cumulative distribution curve of the transformed data and (broken curve) of the fitted normal curve. The abscissae are deviations, in standard deviation units, of the transformed data from the log geometric mean (the arithmetic mean of the logarithms). It will be seen that the normal curve overestimates the proportion of samples found to exceed the geometric mean except at very large deviations, but is never incorrect by more than 5%.

In practical work, it appears that the assumption that the logarithms of dust concentrations on a face vary in accordance with a Normal law of constant standard deviation will not lead us far astray. We may safely use for such transformed data the statistical devices, such as standard errors, appropriate to normally distributed variates. For the recording of averages, however, the transformation is unnecessary. The simple arithmetic mean of a set of samples is an unbiased estimate of the true mean concentration even if the distribution is lognormal; that is, in the long run, the means of such sets will be scattered evenly above and below the true mean, and *their* mean will tend ever closer to it as the number of sets of samples increases. It can be shown, however, that the scatter of these means will be larger than that of some other estimates derived from the samples. They are in fact *inefficient* estimators, which do not make full use of the information given by the samples about the true mean. In some situations the excessive scatter of inefficient estimators can be a serious source of loss. It was observed by Sichel (1952) that the distribution of richness of ore in gold mines was lognormal, with a large standard deviation, and that in consequence if costly errors in interpreting samples of ore were to be avoided, it was essential to use estimators other than the arithmetic mean of the samples. However, the inefficiency of the arithmetic mean in a distribution with such a standard deviation as we have found is too small to be of any practical importance. Finney (1941) shows that the loss of information in this case will amount to no more than 1%.

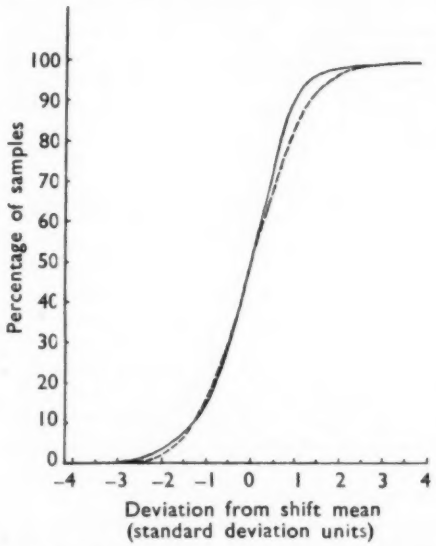

FIG. 3.—Cumulative distribution of deviations of 779 transformed samples from their shift means (full line) and of the fitted Normal curve (broken line).

* The standard deviation of the Normal curve has been estimated from a number of small sets of samples; the divisor used was therefore the total number of samples less the number of sets of samples. This gives the best estimate of the population standard deviation, but it will be, on the average, larger than the standard deviations of each small set of samples.

Finney's results are, however, necessary in order to find the relationship between the arithmetic and geometric means in samples from a lognormal population to enable us to interpret the results of statistical calculations, such as of the percentile points of the distribution, necessarily made with the logarithms of sampling data. Such results would be expressed in terms of geometric mean concentrations, and would need to be converted into terms of the ordinary arithmetic mean.

Finney shows that an efficient and unbiased estimator of the arithmetic means of a lognormal population is obtained by multiplying the geometric mean of the sample of n by a function $g(\frac{1}{2}s^2)$, where s^2 is the usual unbiased estimator of the population variance derived from the sample, $\Sigma(x-\bar{x})^2/(n-1)$, the xs being the natural logarithms of the sample concentrations, and g(t) can be expanded as the series

$$1+\frac{n-1}{n}\cdot t+\frac{(n-1)^3}{n^2\cdot 2!}\cdot\frac{t^2}{n+1}+\frac{(n-1)^5}{n^3\cdot 3!}\cdot\frac{t^3}{(n+1)(n+3)}+\cdots$$

By simple extension of his results it can be shown that when, as in our case, the variance has previously been estimated with a large number of degrees of freedom, an efficient estimator of the arithmetic mean is given by the geometric mean of n samples multiplied by $g\{(n-1)(m+1)s^2/2mn\}$ where m is the number of degrees of freedom upon which the estimate s^2 is based. In our case m = 776, and using $s = 0{\cdot}2203 \times \log_e 10$, the multiplier becomes

$$1 + 0{\cdot}128634\,(n-1)/n + 0{\cdot}008252\,\{(n-1)/n\}^2 + 0{\cdot}000352\,\{(n-1)/n\}^3 + 0{\cdot}000010\{(n-1)/n\}^4 + \ldots$$

The values of this function are shown in Fig. 4 for different values of n, the number of samples per day, in the form of the percentage addition to be made to the geometric mean of the sample.

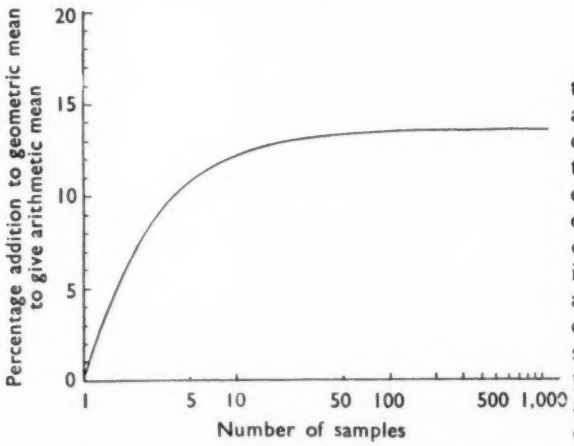

FIG. 4.—Relationship between estimated geometric mean and arithmetic mean for different numbers of samples.

TABLE 2
PERCENTILE POINTS OF DISTRIBUTION OF CONCENTRATIONS WITHIN A SHIFT *

Percentile	Lognormal Curve	Experimental Curve
1	27·3	21·8
5	38·7	36·3
10	46·5	46·2
20	58·1	59·8
30	68·2	69·7
50	89·3	88·0
70	116·1	110·3
80	136·4	123·7
90	170·5	142·7
95	205·0	165·7
99	290·0	288·0

* Percentile points are expressed as percentages of the mean concentration; e.g., 10% of concentrations would be expected to be less than 46% of the mean concentration, while 1% would exceed 290% of the mean.

For large n, the addition stabilizes at 13·72%, and over the range from 6 to 12, in which most of our sets of samples lie, the value of 12% is an adequate approximation. If we assume, therefore, that the arithmetic mean of our samples is on the average 112% of the geometric mean, we may then convert the percentile points of the distribution of observations, which have been obtained as percentages of the geometric mean, to percentages of the arithmetic mean by multiplying each by the reciprocal of 112%, that is, 89%.

The percentile points of the lognormal curve and of the experimental curve are shown in Table 2. Reference to Fig. 1 suggests that the percentile points of the whole set of results fall somewhat closer to the lognormal curve than to that derived from the random collier results. The lognormal curve remains, as was suggested, a good approximation to the truth.

Discussion

Although the variation of dust concentrations at the coal-face during a single shift is great, it now appears that it is nonetheless regular and predictable, and, to a very great extent, closely related to the average concentration. It is necessary to consider if this finding really represents a property of the dust conditions, or if it might be, to a greater or lesser extent, an artifact produced by the sampling instrument or method. It is difficult to conceive of anything in the sampling methods which could cause an artificial regularity of variation. The sampling instrument used, the thermal precipitator, produces a deposit of dust upon two cover-glasses, a small fraction of which (about 1%) is subsequently examined and counted under the microscope. The deposit is not uniform, but shows systematic changes from place to place. If it were

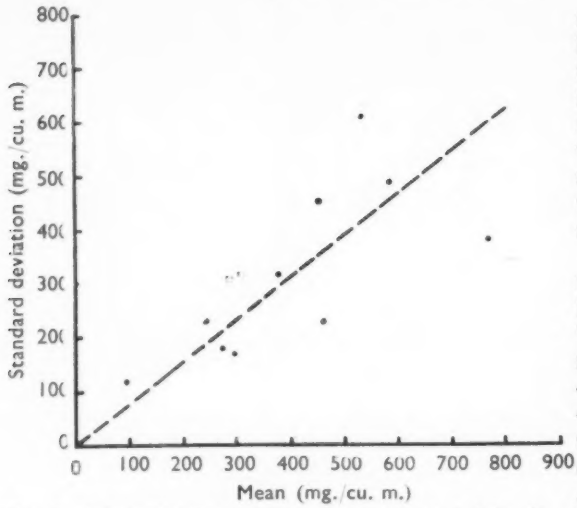

FIG. 5.—Relationship between mean and standard deviation in gravimetric sampling results given by Briscoe and others (1943).

uniform, it is known that an error due to random variation in the deposit must result since only a fraction is counted. In addition, the count will be subject to observer error. These errors will be of a kind which would increase with dust concentration. However, from unpublished results obtained at this Unit it has been estimated that the overall effect of these factors is to produce a standard error of about 5 to 10% of the count, a source of variation considerably smaller than that found. This standard error must be included in the apparent variation, and may be in part the cause of the observed deviations from an exactly lognormal distribution, but its relative importance is small.

The standard deviation in units of log (particles/ml.) has been estimated as 0·2203 ; its antilogarithm, 1·66, may be interpreted as a proportional standard deviation of 66% about the geometric mean. This of course is not the same figure as would be obtained by expressing the standard deviation of the untransformed observations as a percentage of their mean (the coefficient of variation). The latter figure could be most misleading as a basis for calculating standard errors in view of the non-normality of the distribution and, as Finney (1941) points out, is a most inefficient statistic for estimating the true standard deviation of the distribution, equivalent, if we assume an exactly lognormal distribution, to discarding 35% of the data. From Finney's results we may deduce an efficient estimate of the standard deviation to be the geometric mean multiplied by the square root of

$$g\{2(m+1)(n-1)s^2/mn\} - g\{(m+1)(n-2)s^2/mn\}$$

where g is the function defined above and m, n, and s have the same meaning as before. This function has a similar form to that shown in Fig. 4, and with the value we have found for s and m equal to 776 it increases from 0·542 when n = 2 to 0·616 when n is infinite. Over the range from n = 6 to 12 the value 0·60 is a close approximation. Thus the standard deviation of untransformed samples would be expected to be 0·89 × 0·60 of their arithmetic mean, or 53%.

The only estimates of the standard deviations of thermal precipitator samples that have been found in the literature are those given by Bedford and Warner (1943). Their estimates for five collieries range from 40 to 60% of the mean, averaging 44·7% if samples taken after shot-firing are excluded, 48·6% if they are not. It can be shown that this simple average of the coefficients of variation always gives an underestimate of the true value. A better figure, though still a slight underestimate, is their root mean square. In this case the difference is small, the root mean square estimates being 45% and 50·3% respectively. In view of the fact that their samples were usually taken over 20 minutes, and so should vary less than ours, but probably extended for more than one shift, and so included changes in the level of the shift mean, little can be deduced from the comparison except that the order of magnitude is correct.

The distribution of mass concentration of total airborne dust given by Briscoe, Holt, Spoor, Matthews, and Sanderson (1943) provides further evidence that the lognormal distribution of concentrations is real and not artificial. From their Table XLII it may be seen that the distribution of mass concentrations was skewed in the way expected of a lognormal distribution. From their Table XL the standard deviations for each set of data have been calculated (by multiplying the standard errors quoted by the square root of the number of observations) and these are compared with the given average concentrations in Fig. 5. It will be seen that the standard deviation increases with the mean, averaging about 78% of it. The root mean square is 88%. It would be expected that mass concentrations of total dust would be more variable than number concentrations, since the presence or absence of a few large particles would make substantial changes in the total mass.

Further evidence is provided by a personal communication from Mr. D. Young, who has informed me that in his routine dust sampling in the copper mines of N. Rhodesia, in which the sampling instrument was a konimeter, he has observed that the proportion of samples exceeding the mean by given multiples remains constant,

although the mean level of concentration has been steadily diminishing during the past few years.

It appears justifiable to assume that the lognormal law of constant proportional standard deviation that has been observed in the present data is a property of underground dust conditions that would appear whatever the sampling instrument used. Certain deductions of a practical nature can at once be made. In the first place, the accuracy of the mean concentration during a shift estimated by thermal precipitator sampling can be specified in advance. The standard deviation of 20 ml. samples in units of log (particles/ml.) has been estimated as 0·2203 ; in consequence the standard error of the mean of n such samples will be $0{\cdot}2203/\sqrt{n}$ and 95% fiducial limits to the mean will be given by $m \pm 0{\cdot}4318/\sqrt{n}$. Taking antilogarithms, and remembering that the geometric and arithmetic means will be practically proportional, we may express the accuracy of average concentrations for the shift in terms of proportional limits, as in Fig. 6. For example, a set of 10 20-ml. thermal precipitator samples will enable us to state that there is but one chance in twenty of getting the observed mean if the true shift mean lies outside the range of 73% to 137% of the observed mean. Even if 50 samples are taken, the limits reduce only to 87% and 115%, a range of some 23% of the calculated mean.

Only if sampling were continuous throughout the shift would this range of uncertainty disappear. With an automatic dust-sampling instrument such continuous sampling would fall within the bounds of practical possibility, and the need for such an instrument is made even clearer when it is remembered that the ultimate purpose of all dust sampling in coal-mines is to estimate what dust may be inhaled by coal miners as a result of mining operations. Pneumoconiosis appears very slowly ; the contribution of a single day's exposure must be minute. It is clearly necessary to measure and control the dust conditions by means of sampling throughout an extended series of days. If sufficient samples are taken by means of a hand-operated instrument to give a reasonably accurate estimate of a single day's concentration the number required to cover a longer period becomes prohibitive. If on the other hand only a few samples are taken each day but many days are covered, random fluctuations at least as great as those revealed in the present data will appear in the daily averages. By means of a system of quality control, such as is used to monitor the output of industrial processes, the results could be satisfactorily utilized, but the cost of the method would be excessive. An automatic sampling instrument is the only economical solution.

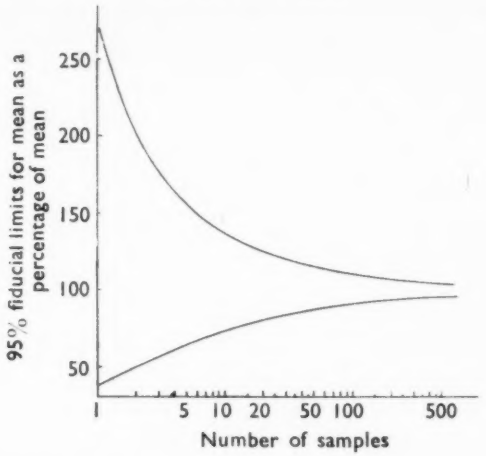

FIG. 6.—Ninety-five per cent. fiducial limits for the mean concentration obtained from different numbers of thermal precipitator samples.

Finally, it is of some interest to consider if any light is thrown on the nature and consequences of " approved conditions " by the present findings. Approved conditions are expressed in terms of the permissible concentration of airborne dust, the standard for non-anthracite collieries being " not more than 850 particles per c.c. between 1·0 and 5·0 microns in size ". The National Coal Board circular CD/354 (1948) remarks that " The standards are not meant to be peak measurements. They are meant to show the conditions as determined by several measurements made at representative times and points. The measurements from which the averages are calculated are, therefore, not to be made in abnormal conditions." Subsequently, another circular (National Coal Board, 1949) gives detailed proposals for the method of sampling to be adopted. This states that " the standards are to be interpreted not as defining the allowable average concentration of dust over the *whole period* of a working shift but the average dustiness *during periods of maximum dust production* ". It is made clear that these periods are not those of momentary peak concentrations, but rather of whole sections of the working shift. On the filling-off shift the first four to four and a half hours are suggested as being the period of maximum dust production, but any exceptionally dusty spell of, say, one and a half hours during this period should be considered separately.

Evidently it is not possible to determine from these rules alone what connexion there will be between the overall average of the shift and the average of the " period of maximum dust production ". It is,

however, the former figure which, in conjunction with the time over which it holds, determines the dose of dust which the colliers receive, and the connexion between the two is thus of great practical interest. The practical interpretation of the administrative instructions quoted above has come to be (Hicks, 1953) that conditions are taken as being " approved " if 90% of samples taken when work is in progress on the face do not exceed 850 particles/ml. We may thus refer this criterion to the results we have presented here. The work of Wynn and Dawes (1951) shows that within the microscopic size range the size distribution of airborne dust is remarkably constant. Thus although the concentration of 850 particles/ml. is specified to relate to dust between 1μ and 5μ, a constant factor of proportionality will convert this to the range we have used, 0·5μ to 5μ, and this descrepancy may be ignored. The proportional relationship between the mean and the 90% point will be the same whichever range is used.

Fig. 3 shows that if 850 particles/ml. corresponds to the 90% point of the curve, the geometric mean will fall 1·28 standard deviation units below if the normal curve is used, 0·88 standard deviation units below if the experimental curve is used. The corresponding geometric mean concentrations are 444 or 544, and, multiplying by 112%, the arithmetic means are 500 or 610. It is unfortunate that the discrepancy between the two curves is at its greatest at the 90% point, but we can be reasonably sure that this interpretation of approved conditions is equivalent to an average concentration of between 500 and 600 particles/ml. during the working shift, irrespective of the level of activity on the face. Conversely, given an average concentration between these limits, we may be confident that in the long run peaks of concentration exceeding 850 particles/ml. will occur regularly during 10% of the working time. In fact, if it be maintained (despite the lack of any evidence to that effect) that it is solely such " peaks " that constitute a serious risk to health, no difference in sampling procedure is required. A technique which estimates the average level of concentration and, equally important, the duration of exposure, at the same time estimates the exposure to peak concentrations, since their frequency can at once be deduced.

Summary

Dust samples taken with the thermal precipitator at the coalface by the Pneumoconiosis Research Unit are analysed to show the kind of variation in dust concentration that is experienced.

Although the variability is high, the general run of samples suggests that the range of concentrations is considerably dependent on the average level, and agrees quite well with the assumption of a lognormal distribution of concentrations with an almost constant proportional standard deviation.

In consequence the accuracy to be expected in estimating mean concentrations from numbers of thermal precipitator samples can be specified in advance. The 95% fiducial limits of the mean of 10 such samples are 73% to 137%, a range equal to 64% of the calculated mean. Even 50 samples only reduce this range to 23%.

The necessity is pointed out of automatic sampling instruments, which alone can sample inexpensively for sufficiently long to reduce this sampling error, and which are demanded also from consideration of the aetiology and rate of appearance of pneumoconiosis.

On the assumption that " approved conditions " are such that 90% of dust concentrations during a shift are less than 850 particles/ml., it is deduced that this limit is equivalent to an average concentration of between 500 and 600 particles/ml. throughout the working shift.

I am grateful for the helpful advice I have received from my colleagues in the Pneumoconiosis Research Unit, in particular, from Mr. R. G. Carpenter and Mr. S. A. Roach. Mr. Roach in addition provided the data upon which the work is based. The diagrams were prepared by Mr. F. Meade.

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THE IMPORTANCE OF THE TIME FACTOR IN THE MEASUREMENT OF DUST EXPOSURE

BY

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Measurements of dust concentrations for the estimation of the danger of pneumoconiosis have been carried out in various industries for many years. In some, such as the South African gold fields, they have been made regularly for nearly 40 years, while in others, such as the British coal-mines, regular dust sampling on a national scale has only been carried on for about five years. In other industries again, such as foundries, normally only occasional samples are taken in an attempt to make some estimate of the likely danger of pneumoconiosis. In all this work the main emphasis has been placed on the factor of concentration and little is heard of the possible importance of the duration of exposure.

It is the purpose of this paper to attempt to arrive at an estimate of the relative importance of these two factors, since such an estimate is essential for the proper planning of dust sampling and dust suppression procedures. It must be emphasized that the discussion is concerned only with dusts which are of such low solubility that, if they are dissolved at all, their rate of solution is very low compared with their rate of inhalation and deposition in the lung. Examples of such dusts are quartz and coal, which between them produce most of the serious cases of pneumoconiosis in this country (Ministry of National Insurance, 1952).

For the purpose of this discussion we shall assume, as a first approximation, that the severity of a pneumoconiosis due to a particular dust will be dependent upon the amount of that dust in the lungs. This is obviously not entirely true, but it is necessary to make some assumptions in order to be able to define the problem. Such evidence as exists (Badham and Taylor, 1938, 1940; King and Nagelschmidt, 1945) suggests that even when there are marked changes in pathology, e.g. from simple pneumoconiosis to massive fibrosis in coal-workers' lungs, there is a rough correlation between the amount of dust in the lungs and the severity of the disease. Our problem therefore is, What are the relative effects of concentration and time on the rate of inhalation and the retention of dust in the lungs?

In the absence of any other information, the natural assumption would seem to be that concentration and time are equally important, i.e., that the amount of dust retained in the lungs is proportional to the product of the two, so that an exposure to a concentration C for a time T will have the same effect as an exposure to a concentration 2C for a time $\frac{T}{2}$. This, which might be termed the "average" hypothesis, has been adopted by all workers who have tried to correlate dust exposure with disease incidence, and it is interesting to note that, in spite of the inevitable imperfections in their measurements, all workers who have made such studies have found a reasonable correlation (Bedford and Warner, 1943; Dreessen, DallaValle, Edwards, Miller, Sayers, Easom, and Trice, 1938; Dreessen, DallaValle, Edwards, Sayers, Easom, and Trice, 1940; Flinn, Dreessen, Edwards, Riley, Bloomfield, Sayers, Cadden, and Rothman, 1939; Flinn, Seifert, Brinton, Jones, and Franks, 1941; Roach, 1953; Sayers, Bloomfield, DallaValle, Jones, Dreessen, Brundage, and Britten, 1935).

Even if we knew nothing at all about the mechanism of dust inhalation and retention, the fact that the "average" hypothesis is simple would be in itself a strong point in its favour; although it must be recognized that a simple hypothesis seldom turns out to be entirely satisfactory, it is an essential principle in research that the simplest

* The author was a delegate to the International Labour Office Conference on the Prevention and Suppression of Dust in Mining, Tunnelling, and Quarrying at Geneva in December, 1952. Many of the statements in this paper are based on discussions with mining engineers and others at this Conference.

hypothesis that will fit all the known facts should be adopted. It might be thought, therefore, that in the absence of any contrary evidence the " average " hypothesis would be adopted as a working assumption by those concerned with dust sampling for the prevention of pneumoconiosis. But in my experience there is a widespread belief that this hypothesis is incorrect ; that high concentrations are disproportionately important and lead to a much greater accumulation of dust in the lungs than would be expected on the simple " average " hypothesis. This belief is clearly stated by Drinker and Hatch (1936), who say :

> " A concentration of 40 million particles per cu. ft. in a granite shed, for example, is probably more than twice as dangerous as one of 20 million."

They emphasize repeatedly the necessity for frequent sampling in order to detect " dust floods ", and maintain that to suppose that prolonged exposure to low concentrations is just as serious as short exposure to heavy concentrations is contrary to a fundamental " law of physiology ", namely that :

> " a sub-threshold stimulus (dust inhalation) for a long time produces no reaction, whereas a relatively brief superthreshold stimulus may cause a reaction."

This " law " is really only a description of the way in which certain physiological mechanisms behave. It will be seen, when we come to consider the mechanisms of dust inhalation and retention, that they are not of this type so that the " law " is inapplicable.

In view of their emphatic rejection of the simple average hypothesis, it is unfortunate that the only actual evidence against it quoted by Drinker and Hatch is a statement by Mavrogordato (1923) that :

> " Lesions of silicosis in a mild degree can be produced in an animal by 30 hr. exposure to intense dust clouds, and *one is inclined to suspect* that it is intermittent exposure to relatively dense clouds that is the deciding factor in producing the disease in susceptible human subjects."

Apart from the extremely tentative nature of his conclusions, as indicated by the words which have been italicized, there is no record in Mavrogordato's works (1918, 1922, 1923, 1926, 1940) that he ever actually compared the results of high and low concentrations in animals in such a way as to demonstrate that the higher concentrations were disproportionately dangerous.

Another eminent authority on pneumoconiosis, L. U. Gardner, has stated (Gardner, 1941) :

> " Atmospheric concentration of dust must be high enough to overcome the efficiency of the upper respiratory protection and permit an excess of particles to enter and accumulate in the lungs."

In view of the deservedly high reputation of these authors, it is not surprising that the simple average hypothesis is rejected by many mining engineers, who insist on the necessity of frequent sampling to detect " peaks " of dust production. For instance, Flugge-de-Smidt (1951) remarks :

> " Is it any advantage to obtain average dust counts ? I would say decidedly not.
>
> " The filtration processes of the human body are capable of filtering dust out of the air when that dust is only present up to a certain concentration, say for sake of argument, 300 particles per c.c. Should a person encounter a dust cloud of, say, 1,000 particles per c.c. as registered by a konimeter, then the human body can only cope with, say, 300 particles and the remaining 700 particles enter the lungs. The rate of breathing is another factor affecting the filtering process of the human body. Believing this to be fundamentally correct, I have always stressed the danger of occasional peaks in dust curves as being of prime importance. An average of, say, 200 particles per c.c. over half an hour can have been more dangerous than an average of 300 particles per c.c. if in the first case a number of peaks occurred, and in the second case a smoother curve was obtained. Having taken thousands of dust samples in development ends, I was impressed first of all with the enormous variations in dust production during normal drilling and the very high peaks obtainable when for instance, a machine was collaring. We need an instrument to ' snap-sample ' such peaks and make us aware of such dangers. The thermal precipitator or any other similar instrument is utterly incapable of giving us that information."

Similarly, the National Coal Board in their memorandum " The Sampling of Air-borne Dust for the Testing of ' Approved Conditions ' " (1949), which is the basis of the present sampling practice in British coal mines, state :

> " The Board have accepted that the standards are to be interpreted not as defining the allowable average concentration of dust over the *whole period* of a working shift, but the average dustiness *during periods of maximum dust production*." [Their italics.]

They go on to point out that these periods will vary from colliery to colliery so that it appears that they consider the level of the dust concentrations more important than their duration, as they do not propose to take variations in the latter into account.

Recently, McLaughlin (1953) has reaffirmed that " intermittent exposure to higher concentrations of dust may be more dangerous than exposure to lower concentrations over a longer period ", although he cites no evidence in support of this statement.

Unfortunately, this belief in the disproportionate importance of high concentrations, which may for convenience be termed the " peak " hypothesis, has never been sufficiently clearly defined for its

validity to be tested ; but an essential feature of it appears to be a concept of a threshold mechanism which breaks down under the strain of high concentrations and either allows an excessive amount of dust to enter the lungs or causes an unusual amount to be retained. In view of the popularity of the " peak " hypothesis and its important effect on dust sampling and dust suppression practice, it seems worth while to examine this concept in the light of what is known about the mechanism of dust inhalation and retention to see whether there is any evidence for the existence of such a threshold.

The Mechanism of Dust Inhalation and Retention

Our knowledge of the mechanisms of dust inhalation and retention has recently been reviewed by Davies (1949) and it will not be considered in more detail here than is necessary to decide the merits of the two theories.

Briefly, it is believed that dust enters the respiratory tract suspended in the air breathed, but particles over a certain size (about 5μ diameter) are deposited on those parts of the respiratory tract which are covered with ciliated epithelium and are removed from the lungs completely in, at most, a few hours. Smaller particles reach the alveoli and a proportion of them, depending on their size and the breathing pattern, are deposited on the alveolar walls. The remainder are exhaled again in the expired air. A small proportion of these exhaled particles may be deposited on the ciliated epithelium, but in any case they will not be retained in the lung. Particles deposited in the alveoli can probably only be removed from there by phagocytosis. (A number of workers have suggested (Gross and Brown, 1952 ; Mottura, 1952) that particles are carried out of the alveoli by simple lymph flow, but the exact mechanism by which dust particles are transported does not affect the present argument.)

It appears that only a proportion of the dust-containing phagocytes migrate out on to the ciliated epithelium ; the remainder are carried into the lymphatic system and are deposited in the interstitial tissue of the lung. These interstitial deposits are more or less permanent, and constitute the *condition* of pneumoconiosis. It is evident that, as so defined, pneumoconiosis is a condition by which, to a greater or less extent, all adults are affected, and it is only when the dust is toxic, or if not toxic, excessive in quantity, that a *disease* results. It is obvious that there is room for great difference of opinion about the stage at which the *condition* becomes a *disease*.

In order to be able to examine the " average " hypothesis in the light of this account of the mechanism of dust inhalation and retention, it is necessary to state it as clearly as possible. This hypothesis may therefore be re-stated as follows : *The rate of accumulation of dust in the lung is directly proportional to the concentration of respirable dust in the air*. Thus the quantity of dust retained in the lung after exposure will on the average be directly proportional to the product of the concentration and the time of exposure.

Is there anything in our picture of the mechanism of dust inhalation and retention to cause us to reject such a belief, and make the rate of accumulation of dust no longer directly proportional to the concentration of respirable dust in the air ?

Before we can answer this question, we must first consider what we mean by " the concentration of respirable dust ". For practical purposes, this can be taken to mean the concentration of particles and aggregates below 5μ in diameter, since only they have an appreciable chance of being retained in the lung. It is sometimes suggested that the larger particles could play a part by swamping the ciliated epithelium and preventing their own removal, but this seems unlikely, since the epithelium is very efficient, and even if temporarily swamped during a severe exposure could recover and clean itself as soon as the exposure was over (Barclay, Franklin, and Macbeth, 1938 ; Barclay, Franklin, and Prichard, 1942). In any case, the most important effect of a high concentration of coarse particles would be to produce coughing, which would probably increase the rate of removal of dust from the upper respiratory tract.

Although it is possible that continued exposure to coarse dust might cause permanent damage to the ciliated epithelium, such an effect has not been recorded, and Cummins (1936) noted that in coal miners of many years' standing with severe pneumoconiosis the ciliated epithelium of the bronchi remained intact. Moreover, it must be realized that the results of such damage, though serious, would not constitute pneumoconiosis as it has been defined. The most striking effect would be chronic bronchitis, with chronic cough, which in fact is not an early symptom of pneumoconiosis and may be absent even in the presence of severe dyspnoea and marked *x*-ray changes (Gooding, 1946).

We are left then with the consideration of the effect of concentration of the respirable dust on its inhalation and retention in the alveoli. There appears to be no conceivable mechanism by which concentration could disproportionately affect the rate of dust *inhalation*. It is true that with manual working there is commonly a correlation between high dust concentrations and high breathing rates,

but this correlation is not causal and breaks down seriously when machine methods of mining and dust suppression are introduced. On the other hand, it is conceivable that, as is often suggested, high concentrations could increase the rate of *retention* by overloading the phagocytes and so reducing the proportion which escaped to the ciliated epithelium. This seems a plausible suggestion, but in the first place all those who have carried out dust inhalation experiments on animals, using concentrations much higher than occur naturally, are familiar with the fact that the rate of phagocytosis is always equal to the rate of deposition in the alveoli (Barclay and others, 1942 ; Carleton, 1934). Even after exposure to these very high concentrations, it is rare to find more than a few extracellular dust particles in the alveoli even within a few minutes of exposure, because the actual rate at which dust is deposited in the alveoli is low (about two particles a minute per alveolus in a dust concentration of 10,000 particles/ml.) and well within the capacity of the phagocytes. Such few observations as have been made in man confirm this finding (Heppleston, 1953 ; Policard, 1952). It can therefore be said that dust concentrations high enough to overload phagocytes seriously will seldom occur in practice. It has yet to be shown, moreover, that slowing their rate of migration would alter the proportion of phagocytes migrating to the ciliated epithelium as compared with those entering the interstitial tissue. It is true that very high concentrations of highly toxic siliceous dusts may lead to paralysis of the phagocytes so that they accumulate in the alveoli, but this is an extreme case and leads to acute alveolar silicosis, a rare condition.

From these considerations, it appears that there is no definite physical or physiological basis for the concept of a threshold below which the lungs free themselves completely of dust, as has been claimed (Cummins, 1927) ; on the contrary, the lungs would be expected to start collecting dust from the first breath, and continue to do so throughout their owner's life, and it is of course well known that this is the case ; the lungs of a child are pink, while those of an adult city dweller are grey. On the other hand, there is what might be termed an " observer " threshold, resulting from the fact that a certain minimum amount of dust in the lungs is required to produce perceptible radiological or physiological change. Since a man's working life is limited, dust concentrations below a certain level will not give rise to diagnosable pneumoconiosis at all.

Although, therefore, there are a number of possible mechanisms which might lead to the lungs being unduly affected by high concentrations, they do not seem very probable, and there certainly seems no justification for assuming their existence in the absence of evidence.

The popularity of the " peak " hypothesis, however, probably does not depend only on the weight of the authorities quoted in its favour ; there are three reasons why it might appeal, especially to practical mining engineers. In the first place, men who are exposed to high concentrations of coarse dust, even for short periods, may cough and subsequently bring up dust-stained sputum. They confuse these manifestations with the symptoms of pneumoconiosis, although, as we have seen, they are in fact quite different, and therefore tend to attach great importance to such exposures, while ignoring their exposure to lower concentrations or finer dust which produce no immediate obvious effect.

Secondly, the " peak " hypothesis fits in very well with a sampling procedure which grew up for quite different reasons. An engineer who is trying to suppress dust feels it natural to look for the highest concentrations and deal with them first.

Thirdly, and an important reason for its popularity in the coal industry, there is a confusion with the fire damp danger. It is often said that dust should be treated like gas ; if this is meant to imply either that it is as important a danger as gas, or that its aerodynamic behaviour is similar, few could dispute such a simile. But the danger of gas only arises above a certain concentration level and is immediate ; safety can only be achieved by ensuring that the danger level is never reached, even momentarily, and therefore a policy of continually looking for the highest concentrations is perfectly proper. In the case of dust, however, in view of the relatively long period of exposure which is necessary before any ill effects are produced, this policy is inappropriate unless it is believed that peak concentrations are especially significant, and not simply a proportional contribution to the average.

Practical Consequences

We are left then with the conclusion that there is nothing in our knowledge of the relationship between dust exposure and disease incidence, or the mechanism of inhalation and retention of dust, to substantiate the " peak " hypothesis or to conflict with the " average " hypothesis. It remains to be considered whether there should be any modification of the present sampling and dust suppression practices in the light of this conclusion, since the present practices are so largely influenced by the " peak " hypothesis.

It is frequently maintained that there are several reasons for dust sampling (e.g. Long, 1953) and that a different technique is appropriate for each of them. The reasons given are: (1) Looking for sources of dust production and studying the effectiveness of dust suppression methods; (2) routine control of dust conditions to comply with regulations; and (3) scientific research into the relation between dust exposure and disease incidence. It is claimed that the first two are the province of engineers and officials, who will decide for themselves which methods are most appropriate, while the third is the job of the medical research worker, who may use more refined methods if he chooses.

It is clear, however, that this attitude is illogical; in so far as the engineers and officials are concerned with the same problem as the medical research worker, namely dust as a potential cause of pneumoconiosis, they must measure the dust exposure in fundamentally the same way; that is to say, they must take into account not only the dust concentrations but the duration of the men's exposure to them. It is true that when conditions are bad very rough and ready methods are satisfactory; for instance, the fact that an instrument such as the konimeter will only give the reading "too many to count" in excessively high concentrations does not much matter for control purposes, while it causes considerable difficulty when attempting to measure exposure accurately. But as soon as dust conditions are fairly satisfactory, any further improvement will depend on the use of more precise methods of measurement so that dust suppression measures can be most economically employed. It is at this point that the engineers begin to ask the research workers about "safe limits", and it is then that their interests become identical. The main purpose of dust disease correlation studies is to determine safe limits, and they must be determined with the instruments and sampling techniques that are going to be used as a routine. As we have seen, as a result of the widespread belief in the "peak" hypothesis, most routine sampling is carried out in such a way as to take little or no account of the duration of exposure. Its great disadvantage as a basis for action is that it requires a much more expensive and laborious sampling procedure than the "average" hypothesis and yet, owing to its lack of definition, the information so laboriously obtained is in fact not used except by pooling and averaging it. To measure the average by taking large numbers of short-term samples and then averaging them is wasteful of labour, if automatically averaging instruments are available, unless the individual samples can be used in some way. It will be said, of course, that they can be used to detect important sources of dust production, but it is hard to see how the importance of these can be assessed unless the duration as well as the concentration of the dust production is measured. Also, the individual samples can only be used for the detection of dust-producing processes if careful records are kept both of the dust concentrations and of the dust-producing processes. Thus an automatic, continuously recording dust sampler such as has been described by Lloyd and Winder (1951) for coal mines is not of much value unless its record is accompanied by a corresponding record of the mining procedures, when the man who is keeping the record might just as well be operating the sampler.

It would seem, therefore, to be a more practical procedure in most cases, if the average is accepted as the proper index, to measure it directly in the most convenient way, and leave the problem of deciding which are the important sources of dust production to the man on the spot. To try to help him by giving him a snap sampling instrument such as a "tyndallometer" (Broomhead and Burdekin, 1953), which yields an immediate reading of dust concentration, may be as much a hindrance as a help, as it will tend to direct his attention mainly to sources of high concentration and cause him to neglect those of lower concentration but of longer duration, and therefore equally or more important as contributions to the average. It is true that there appears to be a correlation between high peaks and high averages (Oldham, 1953), but if the average can be measured directly and easily it is unsatisfactory to measure peaks and rely on a correlation which may not be constant. The danger of using a short-term instrument in addition to an averaging sampler is that the operator will tend to attach more weight to the results of his short-term instrument than to the average, and where it differs to ignore the latter.

Apart from its effect on dust sampling practice, the belief in the "peak" hypothesis is liable to cause some misdirection of energy in the practice of dust suppression. For instance, great stress is laid on the danger arising from such processes as shot firing or the blowing out of drill holes. In the absence of good ventilation these processes, which undoubtedly produce a large quantity of dust and momentarily very high concentrations, are certainly an important source of danger. But once ventilation is established the dust produced is rapidly diluted and carried away, and the danger from these processes is thus correspondingly reduced, and may well make them less important as a source of dust

production than some less dramatic and conspicuous process, such as for example shovelling, which is carried on for much longer periods.

Conclusion

In conclusion, then, we may sum up by saying that the present widespread belief in an ill-defined " peak " hypothesis is not supported by any evidence ; it leads to a laborious sampling technique and, if the " average " hypothesis is correct, may lead to some misdirection of energy in dust suppression. It cannot be stated with certainty that the " average " hypothesis is perfectly correct ; the most that can be said is that it is a simple and reasonable hypothesis which does not conflict with anything that is known about the mechanism of dust inhalation and retention ; so far as it has been possible to check it, it has been found to correspond with the observed facts about the relation between dust exposure and disease incidence. Since it leads to a much simpler, cheaper and more satisfactory dust-sampling technique, there seems to be every reason for adopting it as a working hypothesis in place of the " peak " hypothesis, which at present holds the field to such a large extent.

Summary

Two hypotheses of the relative importance of time and concentration in the production of pneumoconiosis are widely accepted. On one, the " peak " hypothesis, high concentrations are believed to be disproportionately important, while on the other, or " average " hypothesis, concentration and time are believed to be equally important.

The evidence for and against the two hypotheses is considered and it is concluded that the " average " hypothesis is to be preferred.

The effects of this conclusion on dust sampling and dust suppression practice are discussed.

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AIRBORNE DUST IN COAL MINES: THE SAMPLING PROBLEM

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Dust sampling has played a very important part in the drive against dust in British mines. It is becoming widely realized, however, that the present sampling procedures and instruments are far from satisfactory. Opinions tend to vary on what changes should be made, and the following survey of the problem attempts to reconcile some of the points of difference.

The scene of operations is the coal face, a long tunnel through which a stream of air is drawn; dust is produced locally by a variety of actions ranging from mechanical coal cutting to the impact of boots on the floor, and the problem is to measure the dust hazard to the men working in the tunnel.

It seems useful at the outset to distinguish two main sampling functions, research and routine control. In the research category falls the general task of tracking down the dust, of finding which pits are dusty, where suppression is needed, etc. Routine control is concerned with keeping watch on the dust levels, and giving warning of any dangerous changes. At the moment the main emphasis is on research, but routine control will soon become predominant.

There seems little doubt that for routine dust control a scheme on the lines of the quality control systems of the manufacturing industries represents the only really satisfactory solution. It is sometimes held that a system of routine inspection at regular intervals, say every three months, would be sufficient. But conditions on a coal face are not static; as work progresses they continually vary, and a single survey forms an inadequate basis for pronouncing a face safe for any extended period.

The variability of the dust concentrations is in fact considerable. The experience of the Pneumoconiosis Research Unit (Oldham and Roach, 1952) indicates that with the instruments at present available it is sometimes necessary to continue sampling for more than a week before the "true" average dust concentration can be located within 50% of its value with a reasonable degree of confidence. (In his 1953 paper (p. 227) Oldham is concerned with the accuracy of estimation of the mean concentration for any one shift, and for various reasons does not take into account day-to-day variation; the latter, however, must be considered in any final appraisal of the accuracy of sampling.) These findings refer to sampling with the thermal precipitator, the most accurate of the instruments in current use. Incidentally they bring out very clearly the impossibility of the task which confronts the mining inspectors, who are required to assess conditions on a face from a single brief survey, usually covering only one shift.

An accuracy of $\pm 50\%$ reached after a week's sampling, or about 7% after a year, is not impressive; nevertheless, it would probably suffice, for the onset and subsequent progress of pneumoconiosis of coal miners is very slow. It seems clear from the survey of South Wales miners by D'Arcy Hart and Aslett (1942) that even heavy concentrations of anthracite dust normally take at least five years to produce detectable changes. Clearly in routine control sampling only long-term variations are important, and no sample which relates to a period of less than a week is of any real value. Looked at from this point of view, the great disadvantage of current instruments is that they are grossly uneconomic: the thermal precipitator, for example, collects its sample over a period of a few minutes and each sample is evaluated by counting individual particles. The amount of skilled labour which must be expended to collect and assess a meaningful sample is prodigious. Notwithstanding the good work which has been done with existing instruments, they are very wasteful and the industry cannot afford them.

What is needed is an instrument which will run

for a period of at least a week with the minimum of attention : that is, a continuously operating, automatic sampler. There does not seem to be any compelling reason why a successful instrument of this type should not be developed. A choice of measuring principles is available, as shown by the diversity of instruments which have been used at one time or another. There have, it is true, been differences of opinion over the merits of different units in which dust concentration can be expressed (numbers of particles per c.c., projected area, etc.), but a great deal more will have to be known about the disease before it can be decided which unit is most appropriate ; in any case it has been shown (Bedford and Warner, 1943 ; Wynn and Davies, 1951) that most of the relevant physical characteristics are highly correlated in the narrow size range involved (particle diameter $\frac{1}{2}$ or 1 to 5 microns). What is needed is a cheap, simple and reliable instrument which will distinguish in an ordered and consistent fashion between different levels of dustiness, and the question of the units in which the answer is expressed is largely irrelevant.

Equally unnecessary are disagreements over whether the particle size range should be defined in terms of the projected area of the particles or by the settling velocity, that is, whether the sizes of the particles to be included in the sample should be judged by eye or by an elutriator. However variable the relation between the two properties may be in individual particles, with a substantial number spread over a five or ten to one size range, a high correlation between the results they give must be expected ; and in fact recent trials by the National Coal Board have shown that particle counts obtained by the two methods are practically identical. The choice can be made on the grounds of convenience in instrument design.

The use of automatic samplers brings up another point on which opinions differ, depending on which of two views on the probable relation of quantity of dust to disease is taken. One view is that the total amount of dust collected in the lungs is the important factor determining the severity of disease, and on this basis the average concentration over the whole of the period throughout which the men are exposed is the appropriate measure of the hazard. The other, slightly more complex, is that the higher concentrations are disproportionately important ; that short exposure to high concentrations is more harmful than long exposure to low ones. The influence of this second theory makes itself felt in regulations which require that sampling should be confined to periods when the dustiness is at a maximum. Adherence to a rule of this kind would certainly hinder the production of an automatic instrument. It would also make it difficult to obtain uniformity of sampling practice and comparability of results, since conditions vary from one pit to another and " period of maximum dustiness " does not always have the same meaning. The requirement is in any case unnecessary. Suppose the second or " overwhelming concentration " theory about the disease is accepted, then the index of dustiness used must reflect the frequency of occurrence, the duration, and the magnitude of those concentrations whose magnitude exceeds some critical value. It must also be a statistical index : a mere record of particulars of individual dust " peaks " over periods of time long enough to be of any consequence, would be hopelessly indigestible. Any such index must be a function of the parameters of the distribution of dustiness over the period. In practice, a convenient and sufficiently accurate way of summarizing the relevant properties of the distribution would be to quote its first two moments ; in other words, its mean and standard deviation. But, as it happens, these distributions are of the type in which the standard deviation is predominantly a function of the mean itself, and the standard deviation increases with the mean. So the mean concentration is a valid index of the hazard under the second hypothesis as well as the first. (For a further exploration of this point, see Oldham, 1953.) It would be a relatively simple matter to fix a " permissible level " of the mean concentration which would ensure that the critical concentration (at which the dust was assumed to become harmful) would not be exceeded more than a given small proportion (say 5% or 1%) of the time.

Quite apart from the question of its theoretical validity the use of the mean concentration would greatly ease the development of a successful automatic instrument, for obvious reasons. A number of subsidiary tasks in the maintenance of dust control would also be simplified. Indeed there is every indication that the adoption of a more complex criterion would prove a costly strategic mistake.

There remains the spatial problem : where the instrument should be placed, and whether it should be stationary or mobile. It has often been said that the ideal would be to sample the air which each collier breathes, but it seems that this is unlikely to be achieved within a reasonable space of time and that we must therefore be content with sampling a more general body of air, relying on the high correlation which must exist between the dustiness of the environment and the dustiness of the air which the collier actually breathes. A good

correlation between the " approximate " and the " exact " measurements is quite sufficient for control purposes, and even if exact measurements could be obtained it is unlikely that they would be worth the trouble involved—each collier would have to breathe through a sampling instrument resembling a gas-mask.

The basic element in the spatial problem is the choice between " fixed-point " and " roving " sampling, that is, between keeping the instrument at one position on the face, and moving it up and down the face. The roving principle at first sight seems an obvious one to adopt, but from the control sampling standpoint it possesses serious disadvantages. The axiomatic requirement of control sampling is that the men working in the worst conditions on the face should be protected (the conditions being assessed over a reasonable period of time, since we are not interested in short-term fluctuations). Only the information necessary for achieving this need be collected. The type of roving sample which has been used so far is one in which short-period samples are taken at various points along the face during the working shift, the underlying assumptions being that the location of the maximum dust concentration changes from time to time and that by moving the instrument up and down the face one can ensure that the worst conditions are evaluated. But it seems likely that the first assumption is true only if the measurements are confined to short intervals of time : the location of the maximum concentration may fluctuate from minute to minute or even hour to hour, but when measured over reasonable periods of time it is in general quite stable ; and, as argued above, it is the long-term measurements which matter. Even if this reasoning is rejected, the information we now possess invalidates the assumption that the face can be adequately covered with one or two instruments ; the samples are too small and the variability of the dust concentrations too high.

The current type of roving sample begins to have value only when used to obtain an estimate of the *average* concentration on the face, and it is the right type for this purpose. (" Average " in this context refers of course to the distribution in space, not in time.) But for control sampling purposes, since we are interested not in the average but in the maximum, most of the information provided by the roving sample is irrelevant.

It has been suggested that the " random collier " method described by Oldham and Roach (1952) could be used for control sampling. In this method the sampling instrument is associated with a collier chosen at random (more than one instrument may be used, the number of colliers being correspondingly increased). In control sampling, the collier would retain his instrument for a specified period, when a fresh random allocation would be made, and this redeployment of instruments would be repeated at regular intervals. It will be seen that the scheme is essentially of the roving sample type, and is open to precisely the same charges of irrelevancy and inadequacy. For control sampling purposes it does not suffice to show that " random " or " average " conditions on the face conform to the standards.

The fixed point system is clearly the one to use, if we can predict where the worst dust conditions will occur (the conditions being assessed over reasonable periods of time, since we are not interested in short-term fluctuations). The information collected is all relevant and is fully used, in contrast with that furnished by the roving sample. Indeed it would scarcely be an exaggeration to say, in view of the difficulty of getting a sufficiently reliable measure of concentration, that is, of collecting sufficient information, that the only hope of establishing effective control in the dustier pits lies in the possibility of applying the fixed point method. It must be regarded as fortunate, therefore, that the worst conditions nearly always do seem to occur at the same place, namely, at the return end of the face. The harmful fraction of the dust has such a low settling velocity that the amount lost from the airstream by deposition on the walls and floor of the tunnel is small enough to be neglected ; nearly all the harmful dust raised on the face eventually finds its way to the return end. The concentration of harmful dust normally increases, on the average, from the intake end to the return end, as the air in its path passes more and more dust sources. (Indeed it has been observed by the N.C.B. scientific control staff that the concentration of all airborne dust—including the innocuous heavier fraction—often shows the same tendency.) The appropriate position for the sampling instrument would therefore seem to be at the return end of the face, or perhaps (in single-unit faces) in the return airway itself. This method is of course in fairly common use nowadays, and seems to be a convenient one in practice.

The objection to return-end sampling is that the reasoning underlying it is conceived in terms of average concentrations across the cross-sections of the face, and that men who are working near a source of dust may be exposed to conditions worse than the average in the cross-section at that point, and possibly worse than those in the return end. There are, however, circumstances which tend to mitigate this objection. The collier

does not normally breathe the dust which he himself raises, but that raised by his workmates further up the air stream, and the turbulence produced in the air stream by obstacles such as props and by the movements of the men themselves, tends to even out the dust concentration across the cross section. Moreover the high concentrations of harmful dust which arise near a dust source are associated with clouds of coarse dust which are physically irritating and which are avoided if possible. And, of course, if the collier moves to and fro across the air stream at any point the average concentration to which he is exposed tends to become equal to the average concentration across the cross-section at that point.

However, the question is not disposed of and experimental investigation is indicated. If indeed it should turn out that some men are exposed to conditions worse than those obtaining at the return end of the face, a possible remedy might be to adjust the level of dustiness permitted at the return end to some value which would ensure that conditions on the rest of the face were satisfactory. Otherwise a suitable position nearer to the dust source would have to be sought.

In sampling for research purposes, no hard and fast rules can be laid down. It is certain, however, that a continuously operating automatic instrument would be of immense value, especially if it were readily portable. The need for such an instrument for work in the field of *x*-ray examination has already been noted by Cochrane, Fletcher, Gilson, and Hugh-Jones (1951).

Extensive application of the quality control scheme mentioned above would in time afford a by no means negligible increase in our knowledge of the environmental conditions associated with dust disease. But " conveyor-belt " statistics of the kind this system would produce usually give only broad indications of trends, points for further study, etc., and for detailed investigations the " random collier " method, which is based on modern principles of experimental design, has, as Oldham and Roach show, several important advantages.

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Brit. J. industr. Med., 1953, **10**, 245.

MORTALITY IN RELATION TO THE PHYSICAL ACTIVITY OF WORK

A PRELIMINARY NOTE ON EXPERIENCE IN MIDDLE AGE

BY

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From the Social Medicine Research Unit, Medical Research Council

(RECEIVED FOR PUBLICATION AUGUST 17, 1953)

In the course of studies of the epidemiology of coronary heart disease the suggestion arose that deaths from this condition in middle age may be less common among men engaged in physically active work than among those in "sedentary" jobs (Morris, Heady, Raffle, Roberts, and Parks, 1953). In testing this hypothesis an analysis was made of data in the Registrar General's Decennial Supplement for 1930–32 on occupational mortality (1938). The 70 occupational groups in social classes III, IV, and V, the skilled, semi-skilled, and unskilled workers for whom information is provided (about two and a half million men, some 80% of all the men in these classes), were graded by two experts in industrial medicine. From their general knowledge about the physical effort that the jobs involved they distinguished three catagories: "heavy" work, "intermediate and doubtful", and "light" work. (Details are given in Appendix 2 at the end of the paper.) The mortality from coronary heart disease at 45–64 years of age among the heavy workers was found to be rather less than half that of the light workers. A preliminary report is now made from the same material, the mortality data of 1930–32, on the experience of these groups of workers in respect of other causes of death. The focus in this note will be on middle age, taken as 45–64 years; mortality rates in younger and older men will be presented only in relation to the trends during middle age. The years 1930–32 are the latest for which such information is available. The following are the mortality rates per million for men from all causes:

MORTALITY RATES FOR MEN AGED 45–64 YEARS FROM ALL CAUSES

Age	Heavy Workers	Intermediate and Doubtful	Light Workers
45–54	10,208	12,561	11,150
55–64	21,042	25,782	23,757

Mortality from Accidents

Table 1 and Fig. 1 present in detail the rates for fatal accidents. There is a definite tendency for mortality to be greater in heavy workers than in light. This is not unexpected in view of the high proportion that industrial accidents formed of all fatal accidents to men during their working life—perhaps as much as 40% in 1930–32. All miners

TABLE 1

MORTALITY FROM ACCIDENTS IN HEAVY AND LIGHT WORKERS DURING MIDDLE AGE IN ENGLAND AND WALES, 1930–32 (AVERAGE ANNUAL MORTALITY RATES PER MILLION MEN)*

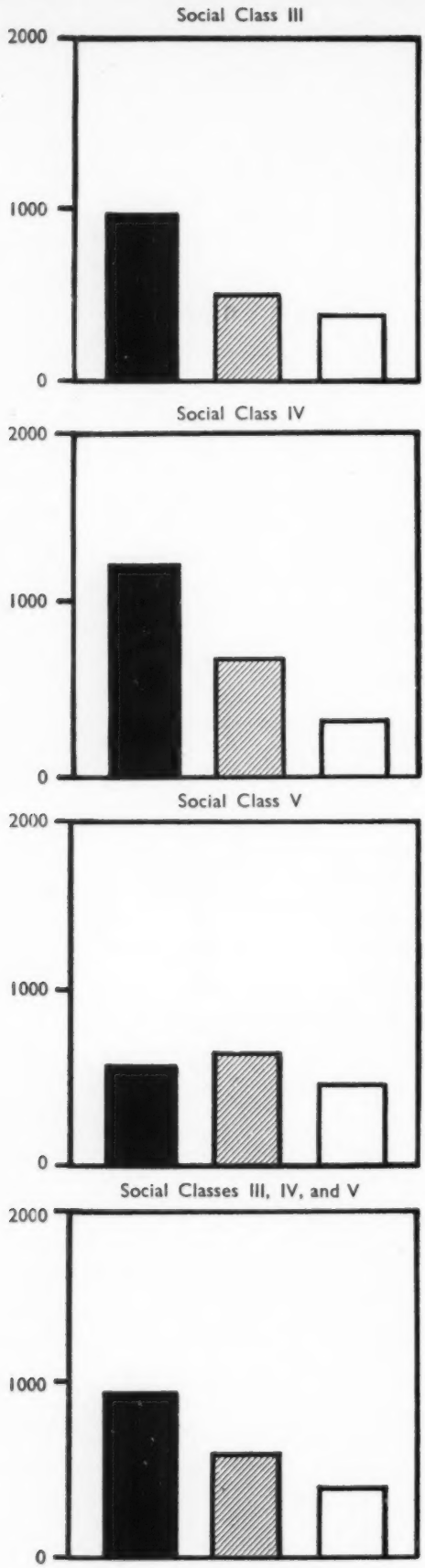
Social Class	Heavy Workers	Intermediate and Doubtful	Light Workers
	Men Aged 45–54 Years		
III	957	431	339
IV	1,198	527	291
V	494	526	323
Mixed	483	—	221
Total III, IV, and V	**864**	**490**	**331**
Total no. of deaths (3 years)	959	1,157	315
1931 census population X 3	1,110,390	2,363,772	951,732
	Men Aged 55–64 Years		
III	1,055	628	499
IV	1,233	895	426
V	679	802	680
Mixed	754	—	312
Total III, IV, and V	**980**	**748**	**500**
Total no. of deaths (3 years)	883	1,389	334
1931 census population X 3	901,005	1,855,875	668,304

Data extracted from the Registrar General's Decennial Supplement, Part IIA, Occupational Mortality (1938).

The classification of the occupation groups was specially made and is detailed in Appendix 2.

Social Class III = Skilled workers.
" " IV = Semi-skilled workers.
" " V = Unskilled workers.

*The figures include all types of fatal accidents. It is not possible to distinguish occupational from other accidents.



were classed as heavy workers, and during 1930–32 fatal accidents in mines and quarries alone accounted for almost a fifth of the total of accidental deaths among men in social classes III, IV, and V (Ministry of Fuel and Power, 1951). Particularly dangerous jobs on the railways and in building are also reflected in the Table. The large number of miners as well as the presence of the railway platelayers (the most hazardous of the main categories of railway workers) in social class IV accounts for the fact that the mortality rates of men in that class are higher than in class III. However, it is the experience of the underground miners among the heavy workers that dominates this picture of accidents.

Table 2 shows that the excess mortality among heavy workers is apparent from 16 to 64 years of age. The trend is not nearly so clear at 65–69 and is not evident at all at 70–74. Occupational mortality statistics after 65 years of age, however, are difficult to interpret because increasing retirement makes the occupational data of the death certificate and of the census return less reliable and, perhaps, not strictly comparable. However that may be, in accidents other causes which are not related to occupation become much more important among the elderly.

TABLE 2
MORTALITY FROM ACCIDENTS IN HEAVY AND LIGHT WORKERS AT DIFFERENT AGES IN ENGLAND AND WALES, 1930–32, IN SOCIAL CLASSES III, IV, AND V COMBINED (AVERAGE ANNUAL MORTALITY RATES PER MILLION MEN)

Ages (years)	Physical Demands of Work		
	Heavy	Intermediate and Doubtful	Light
16–19	754	536	437
20–24	727	654	544
25–34	730	441	362
35–44	758	366	237
45–54	864	490	331
55–64	980	748	500
65–69	1,003	1,116	825
70–74	1,205	1,540	1,263

See footnotes to Table 1.

There are no other conditions in which there is a clear tendency for mortality to be greater among the heavy workers. Perhaps we should not have been surprised at this ; on the other hand, the most striking result of the present analysis seems to be the relatively large number of conditions in which there is an excess of mortality among light workers.

Conditions with Greater Mortality among Light Workers

Table 3 and Fig. 2 present the rates in seven conditions in which in middle age, *taken as 45–64*

FIG. 1.—Mortality from all types of accidents in heavy and light workers in England and Wales in 1930-32 ; average annual mortality rates per million men aged 45-64 years.
In the figure black indicates heavy workers; hatching intermediate and doubtful ; and white, light.

TABLE 3

CONDITIONS SHOWING GREATER MORTALITY IN LIGHT WORKERS THAN IN HEAVY WORKERS IN ENGLAND AND WALES, 1930–32, IN SOCIAL CLASSES III, IV, AND V COMBINED (AVERAGE ANNUAL MORTALITY RATES PER MILLION MEN)

Ages (years)	Coronary Heart Disease			Cancer of Lung and Pleura			Diseases of Prostate			Appendicitis			Diabetes			Duodenal Ulcer			Cirrhosis of Liver		
	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.	H.W.	I.D.	L.W.
25–44	*46	*61	*61	*50	*54	*59	—	—	—	48	53	75	43	43	31	53	62	45	—	—	—
45–54	139	225	337	96	158	157	26	28	31	77	83	116	77	84	89	82	137	163	47	59	58
55–64	396	530	866	175	268	301	220	300	334	84	106	151	172	222	332	99	155	172	123	140	199
65–74	1,002	1,274	1,961	182	280	280	1,363	1,618	1,890	94	142	162	491	542	996	115	158	187	232	287	321

*35–44 years. H.W. = heavy workers. I.D. = intermediate and doubtful. L.W. = Light workers.

See footnotes to Table 1

years, the mortality is greater among light workers than among heavy workers. These are, of course, not the only conditions in which this is true, but they are the only ones where the differences pass certain simple objective tests which were used to pick out conditions where the difference meant something in statistical terms. We shall discuss later whether they might mean anything in other terms—medical and social. The statistical tests chosen were: (1) There should be a clear trend for mortality to increase with lightness of work, the "intermediate and doubtful" group lying between the "light" and the "heavy" (Fig. 2); (2) mortality should be greater in light workers than in heavy workers in each of the three social classes (III, IV, and V) separately; (3) mortality among light workers should be at least one-third greater than among heavy workers; (4) the trend should be a fairly general one and not due to any one occupation group or industry.*

Coronary heart disease shows the strongest trend and the greatest excess in the light occupations, but, as said already, mortality among light workers is at least a third greater than among heavy in all the other conditions in the Table. The early appearance of the trends in the conditions to the left of the thick line in Table 3 (the appendicitis rates at 20–24 years, as a matter of fact, are 54, 69, 74) is interesting, as well as the persistence of the trends at 65–74 years of age.

In Table 4 there are two conditions, pulmonary tuberculosis and disseminated sclerosis, with a lesser tendency in the same direction: in each the mortality in the light groups during middle age is at least a third greater than in the heavy, but in disseminated sclerosis the pattern of mortality in social class IV is erratic, and in pulmonary tuberculosis there is an irregular heavy-light trend in the three classes combined.

Conditions with no Apparent Relationship between Mortality and Physical Activity of Work

Death rates were calculated for 20 other conditions in which numbers were large enough, but the results (Appendix 1) showed so little variation in terms of the particular dimension of physical activity in work as to suggest that it was irrelevant to the problems of these diseases, at any rate during the important period of middle age. In particular, the "heaping up" in the intermediate/doubtful column suggests that the approach is not a meaningful one. The contrast between the figures for coronary disease (Table 3) and those in the other cardiovascular causes of death (Appendix 1) is the most striking result. Nephritis (Platt, 1947), and

*Further analysis showed that, cancer of the lung apart, the pattern of mortality in the conditions in Table 3 at 45–64 years is unexpectedly homogeneous. For each of the six conditions, taking occupation groups with at least 15 deaths during 1930–32, the rate in the individual light occupation groups was higher, with only slight exception, than in the individual heavy groups.

TABLE 4

CONDITIONS SHOWING GREATER MORTALITY IN LIGHT WORKERS THAN IN HEAVY WORKERS WITH A LESS CLEAR TREND IN ENGLAND AND WALES, 1930–32, IN SOCIAL CLASSES III, IV, AND V COMBINED (AVERAGE ANNUAL MORTALITY RATES PER MILLION MEN)

Causes of Death	Men Aged 45–54 Years			Men Aged 55–64 Years		
	Heavy Workers	Intermediate and Doubtful	Light Workers	Heavy Workers	Intermediate and Doubtful	Light Workers
Respiratory tuberculosis	1,196	1,829	1,807	1,016	1,626	1,405
Disseminated sclerosis	35	39	54	42	54	69

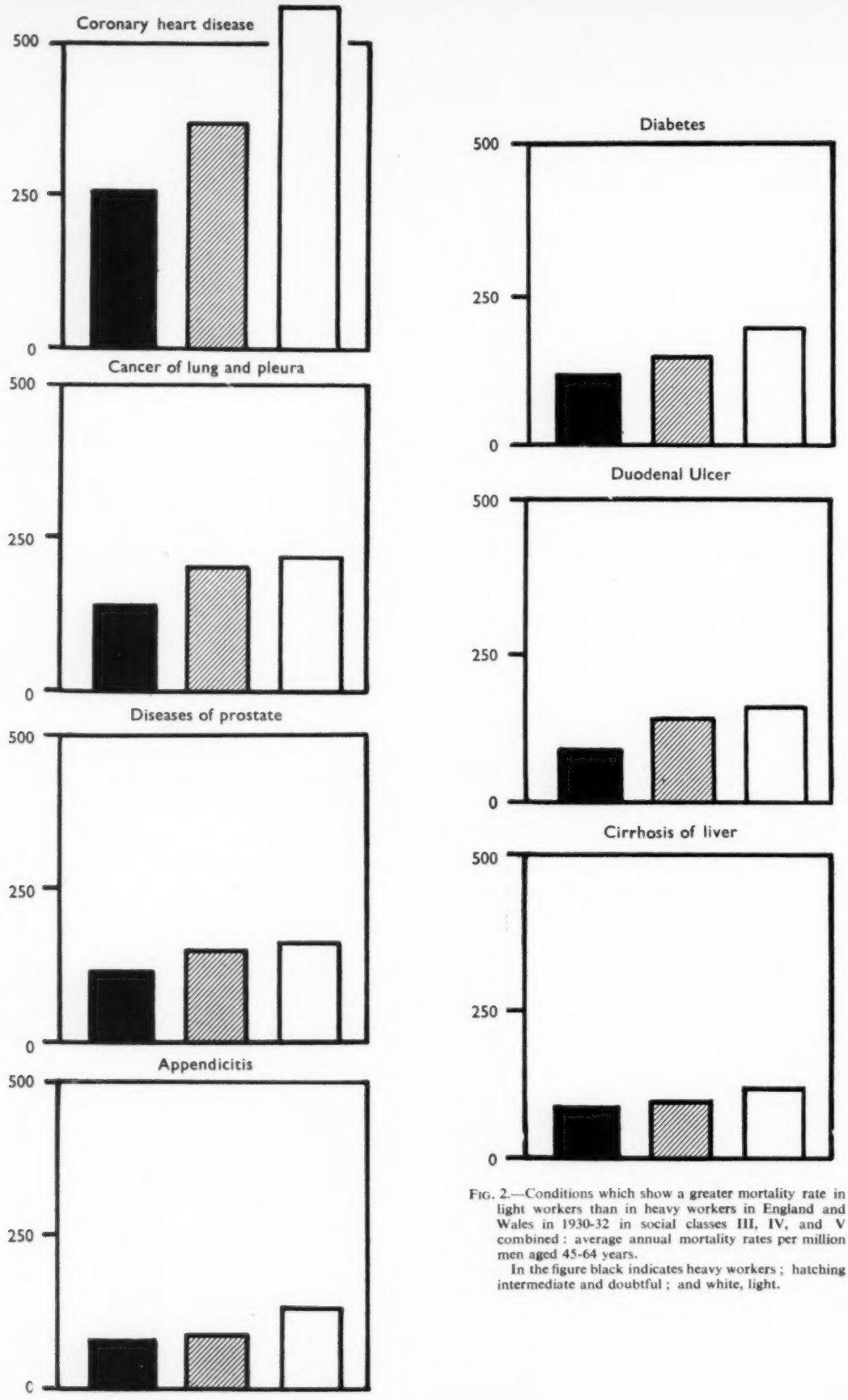


FIG. 2.—Conditions which show a greater mortality rate in light workers than in heavy workers in England and Wales in 1930-32 in social classes III, IV, and V combined: average annual mortality rates per million men aged 45-64 years.

In the figure black indicates heavy workers; hatching intermediate and doubtful; and white, light.

possibly bronchitis might also be considered in the same connexion. The slightness of the trend with *heaviness* of work found in bronchitis and in hernia was unexpected. We cannot understand why there should be any such trend at all in pernicious anaemia. The different behaviour of gastric and duodenal ulcer is notable—another clue from vital statistics on the need to distinguish between these two conditions (Morris and Titmuss, 1944). The syphilis figures (they include aortic and neuro-syphilis) lend themselves to all manner of speculation. In suicide the lower rates among heavy workers is apparent from 25 to 34 years of age and remains to 70 to 74 years.

Occupational Causes and Occupational Results

The main interest of figures such as those of Tables 1, 2, and 3 lies in the possibility that they can provide clues to aetiology. They invite, therefore, a kind of parlour game in which facts, theories, and fancies about the causes and natural history of various diseases are juxtaposed with facts, theories, and fancies about possible occupational factors of disease in the hope that useful hypotheses will emerge. We do not propose to play this game at any length, but before making even a brief comment must stress that analyses like those made in the Tables can be quite bedevilled by change of job *because* of disease. If there is a tendency for doctors to recommend a change from heavy work to light in patients with duodenal ulcer, for example, as there is, or was (Doll and Avery Jones, 1951), the mortality from this condition among light workers may be so exaggerated by such transfers that it could exceed the mortality of heavy workers, even if there is nothing in light work conducive to ulceration, or to death from it. The high mortality among the light workers, that is, would represent an occupational *result* of the disease rather than an occupational *cause*. On the other hand, men may slip down in the scale of skill on account of ill-health, and this may involve a transfer from light work to heavy labouring, for instance, that will inflate the mortality rates of those heavier occupations. It is, therefore, necessary in each individual condition to consider whether this kind of process is likely to be operating before attaching any importance to the figures and beginning to speculate on their possible connexions with aetiology.

It was a safe prophecy that the trend in accident mortality would be found, though perhaps not such a strong one, and it is quite unlikely that change of job on account of the accident that proved fatal has materially affected the pattern displayed in Tables 1 and 2 and in Fig. 1. Table 3 therefore, represents the crux of the problem, and whether we can begin to spin interesting hypotheses about occupational causes of the diseases concerned must depend on the strength of the prima facie evidence that we are not dealing, as said, only or mainly with occupational results of these diseases. There is no point in proceeding further until this problem is out of the way. In the four conditions to the left of the thick line in Table 3 it may be claimed with some reason that the trends are unlikely to be a simple artefact of change of job. In coronary heart disease there is evidence that a majority of all deaths in middle-aged men occur during the early stages of the first clinical episode of the disease, i.e. before there is opportunity to change occupation on account of it (Morris, Heady, and Barley, 1952). In fatal appendicitis, in cancer of the lung, and in prostatic disease clinical experience does not suggest that men will have transferred in large numbers from heavy work to light after the illness has presented.

In the three other conditions analysed in Table 3, diabetes, duodenal ulcer, and cirrhosis of the liver, the situation is different, and there is every reason to suppose that job selection *because* of the disease specified played a part, and it may be a big part, in producing the mortality trends. It is not possible, however, to be sure that this is the whole story. For instance, a small group of occupations was extracted from the light groups of social class III into which it is most unlikely that men would transfer because of these three diseases. Mortality still remained higher in these particular occupations than in the heavy jobs of class III. These occupations were potter, compositor, french polisher, railway engine driver, railway signalman, and the police. This observation, of course, deals with only one side of the question : that light workers have high mortality rates, but there is a little other corroborative evidence also. It is interesting, for example, that the figures for gastric ulcer (Appendix 1), in which condition a change of job was also probable, show no such clear rise of mortality with diminishing physical effort as does duodenal ulcer. Moreover, in neither duodenal nor gastric ulcer is this heavy–light trend seen at 25–44 years of age (and there is no trend in duodenal ulcer at 20–24 either). Because of the coding rules in force in 1930–32 the mortality ascribed to diabetes is probably more correctly regarded as " mortality from various causes " in men with diabetes. Yet, coronary heart disease apart, none of the conditions associated with mortality in middle-aged diabetics, such as cerebrovascular disease and " arteriosclerosis " (the " nephritis " is probably too remote to consider)

shows nearly so clear a heavy–light trend as do the diabetes rates. Perhaps the diabetes trend of Table 3 represents a combination of the important coronary element in diabetic mortality together with a diabetic element itself (see also Joslin, 1937). The mortality among young diabetics, at 16 to 24 years of age as well as 25 to 44, shows, if anything, an opposite trend to that found in the middle aged and elderly. Initial or late preference for light jobs, if it was a major factor, might well have been expected to show up even more strongly at younger ages. (This difference in the behaviour under and over 45 is interesting also because of the different clinical–pathological types of diabetes common in youth and middle age.) In cirrhosis of the liver it may be mentioned that the excess in the lighter occupations cannot be explained by the inclusion in this category of occupations connected with alcoholic drinks. It persists if these occupations are excluded.

Comment

The fatal accidents figure of Tables 1 and 2 are a special problem and need not detain us now. In the light occupations of Table 3 we are left with an interesting list of conditions that reads like part of a catalogue of the "diseases of civilisation"—coronary heart disease, cancer of the lung, duodenal ulcer, appendicitis, diseases of the prostate, and diabetes. (How the "cirrhosis" of 1930–32 should be regarded is not clear.) The first three of these are the "new" conditions which have afflicted in particular the middle-aged men of the western world, and now cause untold illness and probably over 20,000 deaths a year in males aged 45–64 in England and Wales alone. Diabetes apart, all the conditions attack males more than females. It is interesting, too, that none of these conditions are particularly associated with poverty—up till now the main social problem of preventive medicine in this country—and all show higher mortality in the upper social classes or no variation of mortality between the social classes (Registrar General, 1938). This aspect, however, is complicated by the fact that physical activity in work is highly correlated with social class, as evidenced by the sedentary nature of so many of the jobs in social classes I and II. Nevertheless, the present results may suggest one "way in" to the study of the environmental factors of increasingly important public health problems about whose prevention we know little.

In considering what these mortality trends of Table 3 might signify, it is necessary to bear in mind that the relations of work and health are manifold and complicated, direct and indirect, immediate and remote. If it be granted that these mortality rates are not merely the secondary product of selection of job (including complications of this such as the refusal of heavy work to those found at pre-employment examinations to be suffering from certain diseases), it still remains an open question how much these mortality rates are related directly to the physical effort involved in the occupations. Constitutional factors may affect both the initial and later choice of job, and also proneness to particular diseases. Personalities of particular types may find what they need more commonly in light than in heavy jobs and develop diseases also associated with their types of personality while in these light jobs. The physically weak, sooner or later, may try to protect themselves by avoiding heavy work, and suffer while holding their light jobs from the diseases they would have developed in any event, as well as from the diseases causally connected with light work. Such problems need to be investigated disease by disease (see Morris, 1947; Stewart, and Hughes, 1949; Morris and others, 1953). Meanwhile, two things about the table are interesting: the various nature of the conditions with excess mortality in light jobs, suggesting a wide range of dispositions in constitution and experience, and the fact that mortality from all causes combined is little different between the light workers and the heavy, which does not suggest any particular "weakness" of the men in the light jobs. Another kind of difficulty arises because it is exceedingly doubtful how far in the present state of knowledge the physical dimensions of work can be isolated from the psychological and social. The emotional satisfactions and supports of heavy physical work may be the operative factor in any of these diseases that possibly have important psychological components in their aetiology—duodenal ulcer, for example. Or the emotional stresses and frustrations that may well be commoner in jobs classified as light may be influential in the opposite direction. The problem is very complicated because the importance to the individual of the *particular job situation* may often be far greater in respect of its psychological aspects than its physical aspects. It is quite conceivable, moreover, that heavy workers are "tougher", readier to ignore symptoms, and so increase their mortality. (If only we had more facts about the psychological components of work!) Again, the economic aspects of work may be important, though an attempt was made to allow for some of these by considering only conditions in which there is a trend in each social class, whatever the difference between the social classes might be. It has been suggested, for instance, that unemployment may be

associated with a falling mortality from peptic ulcer (Morris and Titmuss, 1944), and heavy jobs, such as coal-mining, undoubtedly suffered particularly severely from the slump in 1930–32. There are other aspects of work that might be regarded as " social ". Thus in 1930–32, heavy workers were concentrated largely in mining villages and in rural areas. Quite conceivably this was reflected in a lower diagnosis rate of cancer of the lung than was current at the same time in the cities where many of the light workers lived—a social relation of work that has little to do with the heaviness of the labour. Moreover, the low mortality from cancer of the lung among heavy workers is due almost entirely to low rates among coal miners and agricultural workers. There are stringent " no smoking " regulations in most coal mines and rural populations indulge less in the cigarette-smoking habit than urban (Doll and Hill, 1952), certainly a physical aspect of work, but not a matter of the physical activity of the job.* Closer to this physical activity factor are various aspects of diet and its partition between different nutrients. These may be relevant to the trend of appendicitis mortality though, of course, we cannot say anything about the great majority—i.e., non-fatal appendicitis. Meanwhile previous study suggests that in coronary heart disease the association with physical activity in work may be a direct one (Morris and others, 1953). The common outdoor element of physically active work, and the indoor of sedentary, should also be remembered (Vernon, 1939).

It is possible, therefore, that the physical effort which the present classification of occupations was designed to isolate may be only one of many factors operating to produce the trends of Table 3. Physical activity itself, however, may be a factor of health through promoting muscular fitness, cardiac and respiratory efficiency (conceivably improving the coronary circulation directly through its greater exercise with muscular work), and it may be also through its promotion of leanness. If heavy workers are less commonly obese it would be expected that they would have less atheroma, hypertension, and diabetes, and that they would stand operations better (compare the trends in appendicitis and prostatic disease). The physical effort in work may thus be a "general factor " of health, part of a " way of life " promoting good health and preventive not of a particular disease, but of many disorders of structure and function, and finding expression in lower mortality from a variety of " causes ". Such " general factors ", both positive and negative, are of course well recognized in promoting growth and development (balanced diets with fresh foods, for example), in preventing infections (the virtues of unpolluted water, of cleanliness and generous living space), in reproduction (the advantages of youth), in preventing diseases of middle age, (weight control), in promoting mental health (family relations in early life). The identification of these general factors, of healthy ways of living, is a main objective of research in social medicine.

*There is an interesting point in cancer of the lung (Table 3). The trend at 45–64 is not explicable simply in terms of possibilities of smoking at work :—

ANNUAL MORTALITY PER MILLION 1930–32

Workers Aged 45–64	Occupation Groups	
	Smoking Possible	Smoking Prohibited*
Heavy	156	95
Intermediate and doubtful ..	210	136
Light	209	260

*Underground miners, textile workers, workers in chemical processes, potters, etc., french polishers, policemen, printing machine minders, printers, etc. Ref. Code Nos. 4, 5, 6, 7, 8 ; 29, 30, 31, 32, 33 ; 14, 15, 43, 49, 69 (Registrar General, 1938).

The heavy workers with the low rate of 95 are entirely the underground miners. These lose their advantage after the age of 70 though, as said, such rates are particularly difficult to interpret in old people—small numbers apart.

ANNUAL MORTALITY PER MILLION IN 1930–32*

Occupation	Men Aged		
	45–64	65–69	70–74
Smoking prohibited			
Coal miners	95 (81)	192 (20)	297 (18)
Others	199 (51)	185 (6)	201 (4)
All in occupations where smoking prohibited	119 (132)	190 (26)	273 (22)
All in occupations where smoking possible	200 (1224)	274 (232)	250 (131)

*Numbers of deaths in brackets (see also Kennaway and Kennaway, 1953).

Summary and Conclusions

The occupation groups of social classes III, IV, and V in the Registrar General's Occupational Mortality Supplement for 1930–32 were classified into " heavy ", intermediate and doubtful, and " light " in terms of the physical activity involved in the jobs.

Seven conditions were isolated in which there was greater mortality among middle-aged men engaged in light jobs than heavy ones, and in which this excess did not appear to be primarily or only a result of the transfer of men from heavy work to light on account of the diseases concerned. These conditions are coronary heart disease, cancer of the lung, appendicitis, diseases of the prostate, duodenal ulcer, diabetes, and cirrhosis of the liver—a particularly interesting group, as several of them are among the " new " diseases of increasing importance

as health problems. The possibility was considered that there may be a "general factor" of health and disease associated with physical effort and sedentariness in work—that physical work may be "a way of life" conducive to good health—as well as special factors directly or indirectly relating the physical activity of work with the individual diseases.

In only one condition was there significant excess mortality among heavy workers, that for fatal accidents. Underground coal miners had by far the highest fatal accident rate and they were all classed as heavy workers.

Reference is made to the problems of isolating occupational results of disease (such as the changing of jobs because of ill health) from occupational causes; environmental factors from constitutional factors; and the physical components from the unknown psychological, and the multiple social, components of work.

We are very grateful to Dr. R. S. F. Schilling and Dr. R. Murray for making the classification of occupation groups for us; and to Mrs. V. Hall for much heavy work in computing.

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APPENDIX 1

CONDITIONS WITH LITTLE OR NO APPARENT ASSOCIATION BETWEEN MORTALITY AND HEAVINESS OR LIGHTNESS OF WORK IN ENGLAND AND WALES, 1930–32, IN SOCIAL CLASSES III, IV, AND V COMBINED (AVERAGE ANNUAL MORTALITY RATES PER MILLION MEN)

Causes of Death	Men Aged 45–54 Years			Men Aged 55–64 Years		
	Heavy Workers	Intermediate and Doubtful	Light Workers	Heavy Workers	Intermediate and Doubtful	Light Workers
Cardiovascular Conditions						
Valvular disease	612	729	612	1,586	1,752	1,537
Myocardial disease	626	820	656	2,299	2,835	2,442
Cerebral vascular lesions	383	523	487	1,750	2,069	2,141
Arteriosclerosis without cerebral lesion	41	62	56	278	344	283
Nephritis	370	503	496	825	1,022	1,122
Abdominal Conditions						
Gastric ulcer	196	305	241	236	310	302
Hernia	37	39	41	102	127	99
Intestinal obstruction	73	82	89	100	125	118
Gallstones	31	24	32	84	78	124
Respiratory Conditions						
Bronchitis	421	549	334	1,006	1,235	790
Pneumonia	887	1,194	870	1,171	1,661	1,347
Pleurisy	50	56	45	69	74	69
Asthma	95	101	76	148	155	136
Infections						
Influenza	348	380	332	539	580	548
Tuberculosis, non-respiratory	70	83	78	91	101	91
Syphilis, etc.	357	503	366	381	692	623
Cancer						
Buccal cavity and pharynx	132	170	130	499	826	519
Oesophagus and stomach	534	610	496	1,509	1,776	1,407
Miscellaneous						
Pernicious anaemia	66	53	52	205	147	160
Suicide	276	350	374	416	522	488

See footnotes to Table 1

APPENDIX 2

CLASSIFICATION OF OCCUPATION GROUPS FROM THE REGISTRAR GENERAL'S OCCUPATIONAL MORTALITY SUPPLEMENT (1930–32)

Social Class	Heavy Work	Intermediate and Doubtful	Light Work
III	Coal hewers and getters (4)	Gardeners, nurserymen, seedsmen, florists (2)	Potters, ware makers, casters, and finishers (14)
	Iron ore mines — workers below ground (10)	Workers in chemical processes (15)	Fitters, mechanics, toolmakers, etc. (21)
	Furnacemen, rollers, and skilled assistants (16)	Metal moulders and die casters (17)	Plumbers (not chemical plumbers) (27)
	Smiths and skilled forge workers (19)	Textile spinners (cotton) (29)	Makers of textile goods, dress, etc. (35)
	Boiler makers, platers, and iron shipwrights (23)	Textile spinners (wool, worsted, etc.) (30)	Boot and shoe makers, repairers (36)
		Textile weavers (cotton) (31)	Boot and shoe, etc., workers and factory operatives (37)
		Textile weavers (wool, worsted, etc.) (32)	Compositors (42)
		Bakers and pastrycooks (38)	French polishers (49)
		Carpenters (40)	Railway—engine drivers, etc. (52)
		Bricklayers (45)	Railway—signalmen (53)
		Masons, etc. (46)	Postmen and sorters (58)
		Paper hangers, painters, etc. (50)	
		Road transport—motor drivers (56)	Retail salesmen, etc.—grocery (64)
		Domestic servants (indoor) (76)	Retail salesmen, etc.—dairy, meat, fish, greengrocery (65)
		Waiters (79)	Police (69)
		Warehousemen and storekeepers (84)	Hairdressers, etc. (80)
		Stationary engine drivers—not underground—in mines (85)	Typists and other clerks—Civil Service (82)
			Typists and other clerks (other than Civil Service) (83)
Population	193,303	523,668	451,334
IV	Coal mines — workers below ground, other than hewers, etc. (5)	Coal mines — other workers above ground (9)	Skilled workers in gas works service (13)
	Coal mines — conveying material to the shaft (6)	Fitters, mechanics, etc., labourers (22)	Metal machinists (20)
	Coal mines—making and repairing roads (7)	Drillers (hand, pneumatic, or electric) (24)	Metal glazers, polishers, buffers, and moppers (26)
	Coal mines — other workers below ground (8)	Metal grinders (25)	Barmen (78)
		Textile strippers and grinders, etc., cotton (33)	
		Textile dyers (34)	
		Makers of alcoholic drinks (39)	
	Stone miners, quarriers (11)	Sawyers and wood turners (41)	
	Iron and steel foundry — furnacemen, etc. (18)	Road transport—horse drivers (55)	
	Platelayers (47)		
	Boiler firemen and stokers (86)		
Population	220,231	128,606	45,531
Mixed III and IV			Printing machine minders, printers, machine rulers (43)
Population			12,883

APPENDIX 2—CONTINUED

Social Class	Heavy Work	Intermediate and Doubtful	Light Work
V	Other workers (navvies) in building, etc. (48) Water transport—dock labourers (57)	Builders', plasterers, bricklayers', and masons' labourers (44) Railway—porters (54) Costermongers, etc., newspaper sellers (66) General labourers and labourers (so described) (87) General labourers, labourers, and other unskilled workers (88)	Messengers and porters, etc. (59)
Population	108,271	754,275	30,264
Mixed IV and V	Agricultural and gardeners' labourers, etc. (3)		
Population	148,660		
Total population social classes III, IV, and V	670,465	1,406,549	540,012

The number in brackets after each occupational group is the Registrar General's code number. The classification of the occupation groups was specially made. Armed Forces were excluded. The populations are taken from the 1931 Census and are for men aged 45–64 inclusive. These 70 groups alone were examined, and not the individual occupations of which the groups are composed.

THE JULY (1953) ISSUE

The July (1953) issue contains the following papers :—

The Pre-impinger. A Selective Aerosol Sampler. By K. R. May and H. A. Druett.

Studies on the Nature of Silicosis : The Effect of Silicic Acid on Connective Tissue. By P. F. Holt and Sonia G. Osborne.

The Incidence of Peptic Ulcer and Chronic Gastritis Among Swedish Sea Pilots. By Tore Dalhamn.

Acute Poisoning Caused by Ingestion of Ethylene Chlorohydrin. By F. Ballotta, P. Bertagni, and F. M. Troisi.

Night Work and Shift Changes. By S. Wyatt and R. Marriott.

Legislation and Litigation. Comments on the Development of Industrial Law. By W. Mansfield Cooper.

From Factory Inspection to Adult Health Service. A Review of Governmental Administration of Occupational Health. By Milton I. Roemer.

Occupational Health Problems of English Painters and Varnishers in 1825. By George Rosen.

Miscellany :

Preliminary Notes on the Treatment of 50 Cases of Tenosynovitis in Industry. By E. L. Knowles and M. D. Kipling.

An Occupational Hygiene Team. By Peter H. Nash and R. J. Sherwood, with the assistance of Joan Bedford.

The Sewerman at Work. By Andrew Meiklejohn.

Health in the Army. A review by Sir Alexander Hood.

Brit. J. industr. Med., 1953, **10**, 255.

HEALTH PROBLEMS IN THE MANUFACTURE AND USE OF PLASTICS

BY

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The increasing variety of plastic materials produced during the last few years is due mainly to the ability of the modern chemist to synthesize the chemical compounds from which plastics are made. The basis of most plastics today is the synthetic polymer and its introduction has made available many substances hitherto unknown in industry. Modern plastics are manufactured to serve specific purposes so that the synthetic polymers can no longer be regarded as substitutes for those found naturally as cellulose, rubber, and proteins. A wide range of materials can be made from them and so designed as to meet the actual properties required for any particular application.

In addition to the polymer, synthetic plastic materials contain varying amounts of other chemicals as catalysts, accelerators, stabilizers, hardeners, pigments, and so on, which are added to assist and regulate polymerization or to influence the properties of the final material, such as colour and flexibility. Most polymers are chemically inert and under ordinary circumstances the final plastic material should be comparatively harmless. It is admittedly difficult, however, in practice to effect complete polymerization and traces of free monomer or other chemicals may be present which can sometimes produce pathological conditions such as dermatitis.

Polymerized chemicals may be broadly divided into two groups, condensation and addition polymers. They may also be divided into thermoplastic or thermosetting types depending upon whether the polymer is softened or hardened by heating. The change that takes place on heating the thermosetting materials is irreversible.

CONDENSATION POLYMER PLASTICS

Condensation polymers are usually formed by the linkage of molecules with the elimination of water or some other compounds.

Formaldehyde Products

The thermosetting types in this group are those formed by the condensation of phenol, cresol, urea, or melamine with formaldehyde. In the manufacture and use of resins, glues, and moulding powders of this type free formaldehyde may be liberated under certain circumstances, the amount depending on such factors as the ratio of the ingredients, the degree of condensation, and the addition of other chemicals such as hexamethylenetetramine. For the sake of simplicity these products are discussed below in two separate sections depending upon whether they mainly affect the human body externally or internally.

Effects on the Skin.—Formaldehyde and hexamine are well known as primary irritants of the skin and mucous membranes and many factories handling resin glues have had cases of dermatitis at some time or another (Factory Department, 1943). Schwartz, Peck, and Dunn (1943) mention a factory of 800 employees where 600 cases of glue dermatitis occurred during the first six months of operation. In a small leather factory the incidence of dermatitis was highest (28%) in the section where " notorious sensitisers such as formaldehyde, lacquer and Bismarck Brown were used " (Squire, Cruickshank, and Topley, 1950). It has been stated that the actual substance responsible for hexamine and formaldehyde dermatitis is formic acid (Schwartz, Tulipan, and Peck, 1947).

There is another factor that should be considered in assessing the predominant cause of dermatitis as the result of handling some of these products. In their usual commercial form, for example, these formaldehyde glues and resins will adhere to the skin and rapidly harden on contact with it, and Little (1950) considers this to be the primary cause of the more serious outbreaks of dermatitis from them.

Mayers and Silverburg (1936) stress the great variation in the length of time ranging from a few

days to a period of years during which men were exposed to formaldehyde products before developing dermatitis. The same authors express doubts on the value of patch tests, and Silcock (1944) agrees with them, stating that they are of little or no practical value. Bamber (1950) asserts that patch tests are not for casual use and only an expert can make and interpret them. Thelwall Jones (1946) considers that their efficient use is an important aid to diagnosis but emphasizes the many errors that result when they are relied on for this purpose and when they are used to detect primary irritants. In view of these facts no patch tests were carried out on the cases described in this paper. In one investigation Schwartz (1945) determined by patch tests that workers were sensitive to resins containing phenol but to a lesser degree than to hexamine and formaldehyde.

The main products considered in this paper are moulding powders or aqueous glues and resins which are only partially polymerized by intention so that they do not harden on the skin and are easily removed by washing. This may account for the comparatively low percentage of cases of dermatitis in spite of the fact that the products may contain substantial quantities of free formaldehyde. The addition of a hardener to these aqueous glues and resins is generally necessary before they are used commercially as adhesives.

The moulding powders are manufactured by mixing resins with fillers such as paper or wood pulp and may also contain unreacted chemicals which are not, however, present in the finally moulded article. The latter is made by the application of heat and pressure to the moulding powder.

In a group of factories making these partially polymerized glues and moulding powders three clinical types of lesions have been distinguished. In the first the patient has usually worked only a few days or a week in the plant when he suddenly develops an acute eczematous reaction affecting the face, neck, scrotum, and less commonly the flexures. There is oedema, sometimes sufficient almost to close the eyelids, and often a papulo-vesicular eruption which may weep and crust. The hands and arms are generally unaffected. The condition appears quite suddenly during a working shift or a few hours later and is produced especially by fume although fine powder particles may also be responsible. It responds quickly to the removal of the patient from the plant and daily treatment in the ambulance room.

Case 1.—This man was a process worker, aged 45, who had been employed for five weeks on the disintegration of urea formaldehyde powder. Following symptoms of tingling of the face and lips he quickly developed an acute papulo-vesicular eczema of the whole face, neck, and elbow flexures. There was oedema of the eyelids and lips but it quickly subsided when the patient was removed from his job and attended the ambulance room daily for treatment.

The patient insisted on returning to the plant when he had completely recovered and after a few weeks he resumed shift work. Three months later the condition recurred in exactly the same places as were previously affected and on this occasion the man was removed permanently from the job.

Case 2.—This man, aged 61, was employed as a carpenter and for two days before he reported to the medical department he had been repairing windows in the densification section of a urea formaldehyde plant. He also stated that he had not been in this plant for a month or so before this particular job. When seen in the ambulance room he had oedema of the eyelids and face which responded rapidly when he was removed from the plant and treated with a bland lotion.

After recovery this man was also very anxious to be permitted to work in all sections of the factory and after three or four months he was allowed to do this.

In the second type the eruption starts as a typical exogenous eczema affecting the interdigital areas, the backs of the hands, the fronts of the wrists, and forearms. Other parts that may especially be affected are those exposed to friction from clothing, e.g. the wrists, the ankles, the neck, and flexures. The palms of the hands are seldom affected but keratodermia and smooth, glossy finger tips with hyperidrosis is occasionally a feature similar to that seen in the hands of manual labourers. Sometimes there is softening of the finger nails with splitting and scaling but this is much more common with men who have been exposed for a period of years. This type of dermatitis may appear years after the man has worked without harm in contact with formaldehyde preparations and seems to depend upon the actual handling of formaldehyde products or contamination of the skin with syrups, resins, powders, etc.

Case 3.—The patient, aged 36, had worked for six months in the plant on the reaction vessels making urea formaldehyde syrups and had noticed a rash of the forearms for some time before he reported. On examination he had papulo-vesicular eczema of the backs of the fingers and the flexor surfaces of both forearms. Although the syrup is mixed mechanically he had occasionally to extract a sample for testing purposes and did not always wear gloves for this purpose. He was successfully treated in the ambulance room with daily dressings of a bland cream.

Several months later he had a recurrence of the skin condition and on this occasion he also developed a massive oedema of the face which appeared overnight. The hands now showed a more chronic scaly eczema

of the fingers and dorsa which reacted very slowly to treatment although the oedema of the face subsided within a day or two. Shortly afterwards he took a fortnight's holiday when the condition cleared entirely.

The third type of lesion is one in which the eruption may combine the clinical features of the two types described above.

Case 4.—A maintenance fitter, aged 62, developed dermatitis after working on machines contaminated by urea formaldehyde dust. This affected only the hands and arms in the first place and he was removed from the job and given work as a storekeeper following which the condition healed. While in the stores he was one day inadvertently handed a number of valves contaminated with urea formaldehyde powder and within a few hours he had developed a sensitization eczema affecting the face, hands, forearms, axillae, scrotum, and groins. He was taken off work altogether and only slowly responded to treatment extending over a period of weeks. On his return to work he complained that he felt an immediate tingling of his eyes and face even when he entered the factory for a few moments as he did contrary to instructions on one or two occasions. He was finally given work as a commissionaire in a laboratory building far removed from the factory itself and he has had no further trouble during the last few years.

The problem of permanent alternative work for dermatitis cases presents difficulties, and Squire and others (1950) have rightly stressed that each individual case must be given serious consideration before a decision is made one way or the other. It has been found that most cases of dermatitis from formaldehyde occurring in this group of factories become sensitized to it so that they seem more liable to a skin eruption subsequently but a few develop an immunity or possibly take greater care on returning to their work. This is in agreement with Schwartz (1945) but contrary to his opinion urea formaldehyde resins seem to be as potent a cause of dermatitis as phenol formaldehyde preparations. This may be due to the fact that in the cases described by him the glues and resins were of that composition which rapidly hardened on contact with the skin.

In one small factory manufacturing urea and phenol formaldehyde resins, glues, and moulding powders the number of cases of dermatitis were comparatively few as can be seen in the accompanying table. This factory employed an average of between 150 and 250 men at any one time over a period of years but since the labour turnover was high many more individuals than the average number were exposed to risk during each year.

Year	Production (1945 = 100)	Dermatitis Cases	Hours Lost	Lost Time Cases
1945	100	9	1,238	1
1946	150	10	1,292	6
1947	194	11	80	1
1948	260	9	208	4
1949	370	16	96	2
1950	447	15	39	2

This table shows that the amount of time lost each year tends to diminish in spite of the marked increase in production. An interesting feature is the large percentage of time lost by a small number of men. Eighty per cent. of the total time lost was caused by five men (more than half of this was due to one man). Seventy-seven per cent. of the total number of cases of dermatitis lost no time and were successfully treated while continuing to work—occasionally at the same job. During the last two years (1949–1950) only four men lost time and between them accounted for less than 5% of the total time lost through dermatitis.

Effects on Absorption.—The acute effects of formaldehyde vapour on the eyes and respiratory passages are well known; they are frequently produced by vapour concentrations as low as 20 to 30 p.p.m. Lower concentrations may result in watering of the eyes, irritation of the throat and upper respiratory tract (Barnes and Speicher, 1942), but these symptoms often disappear after a short interval (10–30 minutes) as the worker gradually becomes accustomed to the vapour. The inhalation of high concentrations has been shown to produce pulmonary oedema and haemorrhage but the pungency of the vapour usually makes it impossible to remain in atmospheres contaminated to such an extent. The extensive literature on its toxicity is well summarized by the U.S. Public Health Service (1945), but in spite of the vast number of investigations which have been undertaken there is a notable lack of information and conformity of opinion on the possible chronic effects in man produced by the repeated absorption of small quantities over a long period of time.

Fischer (1905) asserts that the inhalation of the gas even in small quantities is followed by bronchitis and pneumonia but few other investigators agree with this statement. A case is quoted by Lile (1910) of a tuberculous patient who was kept in a room saturated with formaldehyde gas for several weeks, during which time the patient actually gained weight and his physical condition apparently improved. These effects are surprising even though the actual atmospheric concentration of formaldehyde in the room is not known. The term "saturated" conveys very little except that the concentration was presumably high. It is possible for men to work without embarrassment in atmospheres contaminated with formaldehyde to an

extent that would immediately produce irritation of the eyes and upper respiratory tract of anyone who suddenly entered such a plant but such concentrations would amount to no more than a few parts per million.

McGuigan (1914) states that the result obtained by Lile is contrary to the experience of most investigators, and he suggests that strong concentrations or large doses of formaldehyde vapour will always produce some inflammatory reactions but these often pass unrecognized owing to the usually rapid and complete recovery. Yonkman, Lehman, Pfeiffer, and Chase (1941) described two men who daily consumed increasing quantities of formaldehyde in water over a period of several weeks until 200 mg. were being consumed each day. No significant changes were found in the blood, and urine tests were negative for free formaldehyde and albumin. Feeding rats with food containing formaldehyde confirmed this low toxicity.

In view of this uncertainty on the effects of absorbing formaldehyde it was decided to undertake an investigation on a group of men in one small factory. This factory was engaged mainly in making urea formaldehyde resins and powders and some phenol formaldehyde resin, each man having been employed for a minimum period of five years. Formaldehyde could usually be detected by smell in most parts of the plant but apart from occasional accidental spillings which might produce high local concentrations, repeated general atmospheric concentration tests revealed no more than 30 parts per million of formaldehyde. The latter concentration was found directly over an open mixer, and as a general rule the figures for most parts of the plant were below 10 p.p.m. which is the permissible concentration if conditions are to be regarded as satisfactory. All these men would presumably have repeatedly inhaled small concentrations of formaldehyde almost daily throughout the period of their employment.

The investigation consisted of a clinical examination, a chest radiograph, and a complete blood count in each case. The only figures given for the blood examination in Table 1 are those considered to be outside the normal limits. A white cell count of 5,000 to 10,000 per c.mm., colour indices, erythrocyte counts, and haemoglobin concentrations within the normal limits for men as described by Hutchison and Hunter (1949) are therefore omitted from the table.

In many instances each man had been employed on more than one job during his years of service and in a few cases men had spent some of the time away from exposure to formaldehyde. The majority however had spent most of their working time in a formaldehyde plant.

Four of the men had developed dermatitis at some time or another but so mildly that it cleared within a few days with treatment in the ambulance room. No time was lost by any of the men from this condition.

Six of the blood counts showed a temporary reversal of the polymorphonuclear-lymphocyte ratio. When the counts were repeated a few weeks later the ratio had returned to normal in five cases.

Four of the men complained of mild dyspnoea on exertion. Of these No. 16 has hypertension with cardiac enlargement and albuminuria while No. 5 had suffered from asthma for several years. All other clinical abnormalities are summarized in the table.

Polyamides

Nylon is the generic name given to all synthetic fibre-forming polyamides. These are thermoplastic and are usually made by condensing a diamine with a dibasic acid and polymerizing the resultant salt by heat under pressure.

Since there are a large number of diamines and dibasic acids the number of possible polyamides or nylons is considerable. A wide variety of articles has been manufactured from nylon, for example, textiles, brushes, bearings, gears, cams and electrical components, to mention only a few. One variety (a condensation product of hexamethylene diamine with adipic acid) has been used to make surgical sutures which have been widely employed with apparently no ill effects. Haxton (1945) states that it causes a minimum of tissue irritation and its use as buried suture material has shown its superiority to catgut, silk, linen and cotton thread.

Another of the nylons has been used in the form of a film as an occlusive dressing, and experiments showed that it modified the bacterial flora of the skin beneath the dressing. Pathogenic organisms such as *Staph. aureus* disappeared within a few days and bacterial colonies were considerably reduced beneath the dressing in contrast to the adjoining skin where they persisted (Bull, Squire, and Topley, 1948). The advantages of these dressings have been shown by Schilling, Roberts, and Goodman, (1950) in the treatment of minor wounds in a controlled clinical trial.

Certain grades of commercial nylon may contain other chemicals besides the various polymers so that each nylon must be considered separately with regard to its toxicity or other properties.

ADDITION POLYMER PLASTICS

Addition polymers are of many types but they have in common their method of formation which is by

TABLE 1

CLINICAL DATA OF 25 MEN EXPOSED TO FORMALDEHYDE VAPOUR

No.	Age	No. of Years Employed	Weight st.	Weight lb.	Blood Pressure	Summary of x-Ray Report of Chest	Complete Blood Count	Other Findings
1	49	13	10	5	140/80	Normal	Normal	Dermatitis (lasted six days—no time lost)
2	46	10	8	3	110/65	Normal	White cells 10,500	—
3	49	5½	10	2	120/65	Old healed focus right upper zone	White cells 11,400	—
4	50	6½	11	5	110/70	Normal	Normal	—
5	47	7½	10	2	120/70	Suggestion of basal bronchiectasis. Old healed focus right upper zone. No evidence of activity	White cells 13,900	Clinical chronic emphysema. Changed his job, left the factory shortly after examination
6	51	6½	9	10	126/80	Normal	White cells 4,100	—
7	43	7½	9	11	110/70	Normal	Normal	—
8	51	11	10	10½	120/80	Normal	Normal	—
9	45	18	7	13	145/90	Normal	Hb. 92%	—
10	45	10½	11	5½	130/80	Normal	White cells 13,250	—
11	35	5	11	3½	140/70	Normal	White cells 12,800	—
12	40	8	10	5	145/90	Normal	Normal	—
13	24	9½	12	5½	120/70	Normal	Normal	—
14	57	6	7	12¾	120/65	Old healed focus left upper zone. No evidence of activity	White cells 11,700	Dermatitis—no time lost. Chest radiograph two years later showed no change from his previous report
15	36	9	7	11	120/70	Calcified hilar glands	Normal	—
16	61	7	10	1¾	160/115	Cardiac enlargement—ventricular hypertrophy. No pulmonary disease	Normal	Cardiac enlargement—confirmed clinically. (Triple rhythm), aortic 2nd+. Pulmonary bases clear. Some evidence of hypertensive retinitis. Urine, albumin++
17	59	6	8	8	140/80	Increased vascular shadows	White cells 14,900	"Arthritis", left elbow and right knee
18	37	5½	10	2½	130/80	Normal	Normal	—
19	38	11	8	0¾	120/70	Normal	White cells 4,500	—
20	53	6	10	11½	150/85	Cardiac enlargement consistent with hypertension. Increased vascular shadows. No pulmonary disease	White cells 11,800	—
21	46	5½	13	10½	170/100	Cardiac enlargement. Vascular shadows increased. No pulmonary disease	White cells 14,100	—
22	60	13	9	6	180/75	Old focus right apex. Shadow left apex. No evidence of activity	R. B.C. 4,860,000. Hb. 88%. White cells 10,000	Dermatitis mildly on two occasions. No time lost. Chest radiograph one year later—no change from previous report
23	49	5	9	8	120/80	Emphysema. Fibrosis both apices and upper zones, probably old infiltration. No evidence of activity	Normal	Mild dermatitis (no time lost). Keratosis palmare
24	44	6	10	2½	120/80	Normal	Normal	—
25	37	8	9	10½	120/65	Slight increased shadows lower zones	Normal	—

the linkage of molecules containing a double bond. The effects of some of these polymers and their derivatives are described in this section.

Polythene

One of the simplest examples of this group is the thermoplastic material polythene (" alkathene ") formed by the polymerization of the gas ethylene under high pressure. It is a long chain polymer containing several hundred CH_2 units and the formula can roughly be represented thus $(-CH_2-CH_2-CH_2-CH_2-)n$.

A brief history and a comprehensive description of the properties of this simplest synthetic plastic have been given by Swallow (1944). In pure form this polymer has been shown by experience to be remarkably innocuous having been used for many medical and surgical procedures involving close and prolonged contact with human and animal tissues (Farquhar and Lewis, 1948). In one notable instance it has been used with apparent success as a substitute for a portion of a diseased femur in a patient (Seddon and Scales, 1949). Although chemically inert it has apparently, under what must be admitted to be exceptional conditions, produced in one case some tissue reaction with giant cell formation and fibrosis, but implantation in the abdominal wall of a guinea-pig showed minimal reaction in this respect (Newman and Scales, 1951).

Vinyl Chloride ($CH_2=CHCl$)

The substitution of one chlorine for a hydrogen atom in ethylene results in an active gas known as vinyl chloride. For ease and safety in transport and handling vinyl chloride is contained in metal cylinders under pressure as a liquid. It is a mild narcotic and similar in its action to ethyl chloride (Fairhall, 1949). Concentrations in the atmosphere should not exceed 500 p.p.m. if working conditions are to be considered satisfactory. It boils at –13·9°C and the liquid will act as a vesicant if it accidentally contacts the skin as can be seen in the following instance :

Case 5.—This man, aged 28, had his hands accidentally sprayed with vinyl chloride. At the time the fingers felt numb and he stated that he had a feeling that his " thumb did not belong to him ". A little later he reported to the ambulance room by which time he had developed a marked erythema of the whole hand and some oedema of the fingers. On the dorsum of the right thumb there was a small second degree burn. The hands were dressed with a bland cream but the following day he had developed second degree burns of all the interdigital clefts of the right hand as well as a small second degree burn of the left index finger. With appropriate treatment the condition healed within two weeks.

Polyvinyl Chloride

Vinyl chloride can be polymerized to produce an inert material, polyvinyl chloride (" porvic ", " geon "). No cases of dermatitis have been observed in its manufacture, processing or handling. A few cases, however, have been reported as the result of contact with the final plastic article which usually contains plasticizers, stabilizers, and other substances besides the polymer. The added chemicals in this instance are not primary skin irritants and there have been no skin lesions in this group of factories which could be directly attributed to them. Common examples are tricresyl phosphate, phthalates, chlorinated paraffin wax, lead carbonate, cadmium and calcium stearate, pigments, etc.

Two cases of dermatitis due to wearing garters, suspenders, and a wrist watch strap made from a plasticised copolymer of vinyl chloride and vinyl acetate have been reported by Zeisler (1940) but he adds that the percentage of such cases is very low in comparison with the large number of such plastic articles in use.

Plasticizers such as tricresyl phosphate and phthalates that are added to polyvinyl chloride increase its flexibility and it should be appreciated that under certain circumstances these substances may " bloom " or " leach " out of the final plastic material. This may be a slow process during which time the plastic deteriorates and gradually becomes brittle. The toxicity of ortho-tricresyl phosphate is well established, and the subject has been fully reviewed by Hunter, Perry, and Evans (1944) who describe cases of poisoning due to its absorption. They state that 3 to 5 g. of the material was a fatal dose to domestic fowls and that it can be absorbed through the skin.

Other chemicals may also be carried out in this " leaching "' process. Lead carbonate, for example, is sometimes used as a stabilizer for polyvinyl chloride, and lead salts have been found experimentally in sufficient quantities to be detected by quantitative analysis in liquids left in contact with plastic tubing or vessels made of this material. No cases of poisoning from these added substances have occurred in the factories mentioned in this paper.

There are fortunately less harmful chemicals that can be substituted for toxic plasticizers to produce a flexible material. The phthalates are a typical example since dimethyl and dibutyl phthalate have been used on the human skin as insect repellants (Anon, 1947). Some of the higher phthalates have been submitted to physiological tests with satisfactory results when they are administered by mouth, by inhalation or applied to the skin

(Appendix *a*). Mallette and von Haam (1952) found that dioctyl phthalate administered intraperitoneally in comparatively large doses proved toxic to animals, but no delayed effect or permanent injury was noted in surviving animals.

Tetrafluorethylene ($CF_2=CF_2$)

The substitution of four fluorine for the hydrogen atoms of ethylene produces an unstable reactive gas known as tetrafluorethylene. This and its polymerized form have been discussed in a previous paper which describes the toxic effects of the polymer under certain exceptional conditions (Harris, 1951).

Methyl Methacrylate ($CH_2 : C [CH_3] COOCH_3$)

Methyl methacrylate, B.P. 100°C, is a colourless liquid with a sweetish, characteristic odour.

It is a mild irritant of the mucous membranes and in a few instances has been known to produce dermatitis. Spealman, Main, Haag, and Larson (1945) state that the instillation of three drops of this monomer into the eye of a rabbit produced immediate irritation with inflammation and oedema within a few hours. Complete recovery occurred after three days. On the skin it produced a very mild irritation which was fleeting in its effects. The writers also describe the toxicity of the monomer when administered to various animals subcutaneously, intraperitoneally, orally and by inhalation, and pathological changes were found in the livers and kidneys resembling the lesions produced by carbon tetrachloride. It is interesting to note that changes were found in the lungs due to its irritant action which in some instances were apparently reversible since healing subsequently occurred.

The same investigators submitted 50 volunteers to patch tests with the result that about one-third of the total developed a mild erythema in 48 hours. About 20% showed evidence of having developed a sensitivity to the monomer when tested ten days later. Polymerized methyl methacrylate similarly tested produced no effects.

The toxicity of the monomer when absorbed by experimental animals has been described by Deichman (1941) who also mentioned its irritant effect on the mucous membranes when inhaled. His experiments show that when absorbed in toxic quantities methyl methacrylate causes an increasing motor weakness, decreased respiration, dyspnoea, and loss of reflex activity ; the animals finally died in coma as the result of respiratory failure.

The atmospheric concentration of methyl methacrylate should be maintained below 1,000 parts per million if working conditions are to be regarded as satisfactory. Its odour can be detected at far lower concentrations.

Cases of dermatitis due to handling this monomer are not common and the few that have occurred in the present group of factories have been of a mild nature, quickly responding to alternative work.

Case 6.—This man, aged 42, was engaged in making decorative plastic models. A great deal of the work was done with bare hands which involved fairly gross contamination with the liquid monomer and compositions containing it. He developed interdigital eczema of both hands but failed to report the condition to the ambulance room for a matter of four or five weeks. When first seen he had a dry, scaling eczema between the fingers of both hands and a papular erythema of the right forearm. This gradually cleared with local treatment and alternative work.

A few cases of dermatitis have been reported in dental mechanics using polymethacrylate and its monomer in the manufacture of dental prostheses. In such instances working conditions are often unsatisfactory so that it is very important to establish the real cause of the skin eruption and patch tests may be of value in these cases. Dental mechanics may be exposed to other irritants than methyl methacrylate and in some instances the use of abrasives (e.g. pumice powder) may have been the cause of the skin eruption.

Polymethyl Methacrylate

Under certain circumstances methyl methacrylate can be converted into a solid polymer that constitutes the basis of many commercial preparations known under the trade names " perspex ", " lucite ", " plexiglas ", " diakon ", " kallodent ", etc. These commercial preparations vary in composition and may contain other chemicals besides the polymer. A brief history of the monomer together with a detailed description of the chemistry, the properties and some of the applications of the polymer have been given by Caress (1944).

The final polymer is like many others comparatively inert, e.g. it is used in the manufacture of contact lenses, artificial teeth, splints, and surgical instruments. Wilson (1946) has quoted 25 patients who had extrapleural pneumolyses by means of methyl methacrylate plombage. According to him the material fulfills all the essential criteria of an ideal for plombage, and ' it is non-irritating to the human body ". For this operation the " methyl methacrylate was moulded into solid and hollow balls " so that it is obvious the writer means the polymerized form although he uses the term methyl methacrylate (the monomer) throughout his paper.

It has been used to replace the head and part of the neck of the femur in operations by Judet and Judet (1950), and in cranial and reparative surgery Jeremiah (1950) used an implantation of polymethyl methacrylate which after three and a half years in position had apparently been successful.

Ridley (1952a) has described 22 successful cases of its implantation intra-ocularly to replace the lens. A later report (Ridley, 1952b) states that over 60 patients have had these lenses inserted at St. Thomas's Hospital and Moorfields Hospital.

Its effects at times however suggest that the polymer may liberate traces of free monomer or in some circumstances decompose on contact with the skin to form the monomer. In a sufficiently fine state, for instance, the powdered polymer can produce a dermatitis like that described above due to methyl methacrylate.

Case 7.—This man, aged 42, had to sieve the polymer in powder form which he transferred from a drum to the sieve using a small hand scoop. His hands were constantly contaminated with the powder and eventually he developed a typical cheiropompholyx which responded very slowly to treatment. He was removed from work altogether for four weeks when the condition completely healed.

This has also occurred as the result of cutting sheets of the polymer with a band-saw when a spray of fine powder or " swarf " may be ejected over the man's hands and if the latter are hot or perspiring the skin is more likely to break down. Here again the original eruption is seen characteristically in the interdigital areas although the backs of the hands can be similarly affected.

Isolated cases have occurred of workers who complained of coughs, sore throats, and upper respiratory tract symptoms as the result of inhaling fine polymethacrylate powder or fume (Anon, 1946). This is not surprising in view of the mildly irritating effects on mucous membranes of the monomer and they can quite easily be prevented by improving the working conditions and particularly by providing local exhaust ventilation.

Methyl α chloracrylate ($CH_2 : CCl : COOCH_3$)

When the methyl radical in the α position in methyl methacrylate is replaced by chlorine the result as might be expected is a compound with markedly irritant properties.

This monomer can be polymerized to form materials similar to those described under polymethyl methacrylate. Methyl α chloracrylate (B.P. 126°C) is a colourless liquid with an odour resembling methyl methacrylate. It is a powerful vesicant whose vapour will produce pulmonary oedema if inhaled in sufficient quantities. A drop or two on the unprotected skin will produce a blister in a day or two even though the affected part is thoroughly washed within a few seconds of the time of application. In this and other presects its properties conform with those described for this group of substances (vesicants) by Goldblatt (1945). The mechanism of vesication is discussed in some detail by the same author. A report on an investigation into its toxicity will be found in Appendix *b*.

Effect of the Liquid on the Skin.—In view of these facts it is not very surprising that specially designed plants and the institution of the most stringent precautions failed to prevent some accidents occurring to those engaged on work with this material, although no serious complications developed in any incident. Methyl chloracrylate penetrates rubber so that protective clothing of this material is inadequate. Some workers were burned in this way from accidental splashes of which they remained unaware because of their protective clothing until the earliest symptoms of smarting and tingling appeared a few hours later or blisters had occurred. An antidote was available for skin contamination in the form of a solution of potassium permanganate (half a dram to the pint).

Case 8.—This man, aged 27, was engaged in polymerizing methyl α chloracrylate monomer on a laboratory scale. He was wearing rubber gloves and stated positively that he did not make contact with the material with his bare hands. When he had finished the job he washed his hands with a solution of potassium permanganate. About three to four hours later he felt his hands tingling and later still noticed small pin point blisters between his fingers. The following day the vesicles had increased in number and the fingers felt irritable and hot. He reported to the ambulance room with several large blisters on the palms of both hands as well as a vesicular eruption of the fingers. These were treated as second degree burns and healed in due course (Fig. 1).

Case 9.—This man, aged 24, was employed making small quantities of methyl chloracrylate monomer in a laboratory. He was wearing protective clothing but removed his rubber boots on one occasion at work because his feet felt hot. Several hours later when he had returned home he noticed a blister on his right foot. The following day he reported to the ambulance room and was found to have a second degree burn of the distal half of the dorsum of the right foot. The blister was incised and tulle gras dressing applied. He remained away from work for a week at the end of which time the condition had practically healed.

An unusual case with some interesting features is worth describing in detail. It illustrates especially that substances which are normally regarded as

harmless may become dangerous under comparatively trivial circumstances. It also stresses the importance of taking a full history and paying particular attention in this instance to the chemistry of the materials involved.

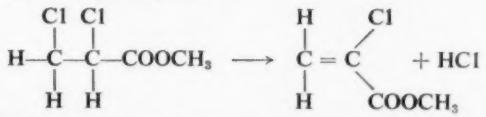
Case 10.—This laboratory worker, aged 24, was distilling methyl α β dichlorpropionate and spilled some of the liquid on to his left hand. He washed it off in the usual way and thought no more of it since previous experience had shown the chemical to be quite harmless. About three to four hours later he felt some irritation beneath the watch strap on his left wrist and thinking it was chafing his skin he transferred the watch to the other wrist. Two hours later he noticed irritation of the right wrist. The following morning when he reported to the ambulance room there were erythematous areas on both wrists. These were covered with tulle gras dressings.

The following day he was away from the district in spite of the fact that the areas had now blistered and he did not report to the ambulance room again until the next day. By this time he had large blisters on the anterior surfaces of both wrists (Fig. 2). The one on the left wrist measured 3 in. × 2 in. × ¾ in. They were incised, the fluid gently evacuated and the blistered skin allowed to collapse. Subsequent dressings with tulle gras produced rapid healing.

FIG. 1.—Vesicular eruption from exposure to methyl α chloracrylate.

FIG. 2.—Large blisters on both wrists following exposure to methyl α β dichlorpropionate.

Methyl α β dichlorpropionate readily loses a molecule of HCl to become the powerful vesicant methyl α chloracrylate.



This must have occurred on the skin beneath the wrist-watch strap through which the original substance had penetrated.

Effect of the Vapour on the Eyes.—The vapour of methyl chloracrylate is markedly irritant even in low concentrations (5 to 10 p.p.m.) so that symptoms of eye irritation with photophobia and lachrymation occur at an early stage. These symptoms may disappear without treatment and if the worker remains in contaminated atmospheres he is very likely to develop a severe conjunctivitis often after a latent interval of a few hours.

Case 11.—This man, aged 25, was employed in a laboratory where a bottle containing methyl α chloracrylate was accidentally broken on the floor. The laboratory was cleared but the patient proceeded to mop up the liquid with the assistance of one other colleague. He stated that afterwards he washed his hands thoroughly and had his eyes irrigated before continuing to work in the vicinity of the accident. Later that evening he developed the typical eye symptoms described above and the following morning he telephoned the medical department to state that he could not open his eyelids. He was brought to the ambulance room and on examination was found to have a severe bilateral conjunctivitis with oedema of the eyelids and intense blepharospasm. Following prolonged irrigation which was continued in the ambulance he was transferred to hospital where he

remained as an in-patient for four days. A report from the ophthalmologist confirmed the findings and stated that both corneas were clear and unaffected. During the first day in hospital irrigation was continued and penicillin drops were inserted into the eyes. Within a few days the condition had completely resolved. This patient illustrated the typical effects of the vapour on the unprotected eyes.

This condition can be prevented in almost every case if the eyes are irrigated as soon as the first symptoms manifest themselves and the practical value of such prophylactic treatment has been shown by the development of eye signs in those who have neglected it. The composition of the fluid used matters far less than the speed, thoroughness and length of time of the actual irrigation. Ridley (1948) recommends 0·65% sodium chloride (NaCl) in distilled water as the most suitable fluid for use as an eye lotion, and asserts that the practice of using " isotonic " solutions is unsound.

Several patients reported to the ambulance room from time to time with mild ophthalmic symptoms while working with methyl chloracrylate over a period of many months. Prophylactic irrigation of the eyes was frequently undertaken and this was either successful in every instance or possibly some of the patients were sufficiently apprehensive to seek this treatment when no exposure to fume had occurred.

Effect of the Liquid on the Eyes.—Splashes of the neat liquid into the eyes occurred on one occasion only. This accident involved two laboratory workers who were sprayed with methyl chloracrylate suddenly released from a flask under pressure when the fume cupboard door was open. These men were not wearing protective glasses with which they were issued.

Case 12.—This patient, aged 25, immediately washed his face under a nearby tap and his eyes were irrigated on the spot by a first aid worker. When seen in the ambulance room he had a bilateral conjunctivitis with first degree burns of the face and neck. Following prolonged irrigation and the instillation subsequently of sulphacetamide drops he was sent to hospital. In spite of repeated irrigation during the next few hours and subsequent treatment under the care of an ophthalmologist, the following day he had marked oedema of both eyelids with intense blepharospasm. The lids could be separated only with difficulty and the conjunctivitis persisted. A few days later he had developed a small corneal ulcer of the right eye. This gradually healed while he was in hospital. He returned to work after about a fortnight's absence and continued to have treatment for the right eye for another week or so until the condition had completely resolved.

Case 13.—This youth, aged 17, was assisting the previous patient and was similarly sprayed in the face with the vesicant. He ran to the nearest ambulance room which he reached within a minute or so. On examination he had an acute bilateral conjunctivitis, the right eye being the more obviously inflamed. The eyes were irrigated for a total of about two hours and he was susbequently detained in the ambulance room for a much longer period. At the end of that time the eye seemed to have cleared and he had no symptoms so that he was allowed to go home. Some hours later, however, the eyes became painful and he was admitted to a hospital in the early hours of the morning. Later in the day he had developed acute bilateral conjunctivitis with oedema and spasm of the eyelids. He responded fairly rapidly to treatment and was back at work within a week. Incidentally this patient had a small second degree burn of the abdominal wall which passed unnoticed until he was examined in hospital since it produced no symptoms and the patient was quite unaware of the fact that he had been contaminated in that region.

Effect of Chronic Exposure to the Vapour.—There was some doubt whether chronic or repeated exposure to small doses might have affected the eyes of workers and it was therefore decided to examine a group of workers after they had been engaged on the work for some months. Thirty-four workers were submitted for examination by an ophthalmologist whose report is summarized below. The men were engaged on a large semi-technical plant manufacturing methyl chloracrylate monomer. The patients were divided into three groups :

Group One : Without history of symptoms of exposure	11 cases
Group Two : With history of mild symptoms of exposure	15 cases
Group Three : With history of symptoms of exposure severe enough to last 24 hours or more	8 cases

The ophthalmologist reported that no patient complained of symptoms at the time of the examination and there was no indication of any abnormal findings that could be attributed to the vesicant.

An additional 18 workers employed on a plant manufacturing the material on a production scale were also examined. The report stated that the only constant pathological finding was a superficial punctate keratitis in five patients. In no case was this more than slight and no treatment was recommended.

No respiratory symptoms occurred in any of the men involved in the work which suggests that atmospheric concentrations were low or that respirators were worn at appropriate times and places according to instructions.

FIG. 3.—Facial oedema after the patient was splashed with chloracrylic acid. His normal features are shown for comparison.

Polymethyl Chloracrylate

As has been stated above methyl chloracrylate can be polymerized under certain circumstances to produce a material resembling " perspex ". The presence of free monomer or decomposition products under particular conditions is suggested by the fact that machining the polymer on a lathe has given off the typical odour of the monomer and in one or two cases has produced eye symptoms. Local exhaust ventilation is sufficient to remove this hazard.

Chloracrylic Acid

A substance resembling methyl chloracrylate in its properties is α chloracrylic acid, and experimental evidence of its effects is given in Appendix *c*.

Case 14.—This man, aged 22, was employed in the laboratory esterifying ethylene glycol with chloracrylic acid when the contents of the flask suddenly splashed into his face. He immediately irrigated himself with water and subseqently with a dilute solution of potassium permanganate before reporting to the ambulance room. On examination he was found to have first degree burns of the face and neck with a mild conjunctivitis of the right eye. Prolonged irrigation of the eye and the application of a bland cream to the face seemed to produce a considerable improvement but by the next day the patient's face had become oedematous (Fig. 3). He also had second degree burns of the interdigital areas of the left hand and on both forearms. The right eye was not inflamed but the cornea showed a central pin head opacity and he was admitted to hospital for further treatment. His condition improved sufficiently rapidly for him to be discharged within a few days. A fortnight after the accident he was seen by an ophthalmologist who reported as follows :

" The cornea shows a near central pin head leucoma which has scarred the anterior epithelium and Bowmans membrane only. It has healed. Near it there are seven or eight minute staining specks on the surface of the anterior epithelium. This will heal without scarring."

On his recommendation the patient continued to have treatment in the form of sulphacetamide drops three times daily for a further brief period. The burns on the hand and forearms were dressed daily until they had healed.

The illustration of this patient's face might well represent the acute effects of formaldehyde vapour with the possible exception that in the latter condition the blisters tend to be smaller and more like eczematous vesicles.

Laminated Plastics

These are plastic materials made by impregnating layers of fabric or paper with resins which are subsequently polymerized by heat and pressure.

Phenol formaldehyde resins have been extensively used for this purpose but more recently new laminates (" marco ", " nuron ", " laminac ") have been made employing far lower pressures than those previously used in manufacture.

The polymers that result from the manufacture of these low pressure laminates are of the cross-linking type having thermosetting properties. Their composition is somewhat involved but a brief description of the chemical and general properties of one of them together with its applications has been given by Burness, Hammond, and Williams (1946).

The actual impregnation of the filler with the resin may be undertaken by very primitive methods, sometimes only the bare hands being used for the purpose. Since the resin is usually mixed with the monomer before application it is not very surprising that cases of dermatitis occur as a result. In some cases dermatitis may be caused by the fabric itself, as for example when woven glass fibre cloth may be used for the purpose (Fairhall, 1949). The resulting skin condition is almost invariably a typical occupational dermatitis affecting the interdigital areas, backs of the hands and wrists, and the arms. It can be prevented by mechanising the process or less satisfactorily by providing the operators with suitable protective clothing.

Discussion

So much has been written about occupational dermatitis that only a very brief reference can be justified here. Instructive accounts of the subject have been given by Squire and others (1950) and by Thelwall Jones (1946), and the preventive measures to be taken in the case of that due to formaldehyde products have been described by the Factory Department (1943). In the factories mentioned in this paper the use of sulphonated oils as cleansers has been found invaluable and they have in fact almost completely replaced the use of soap, which has the disadvantage of rendering the skin unnaturally dry (Horner, 1950). For the same reason they have been found preferable to the soap-woodflour mixture recommended by Cruickshank (1948).

The inefficiency of the usual protective clothing against some chemicals is shown by the effects of methyl chloracrylate on workers wearing rubber boots and gloves and a good example is provided by the illustration of the hand of the laboratory worker (Case No. 8) in Fig. 1.

The compositions of the local applications mentioned in the treatment of the cases of occupational dermatitis described above have been deliberately omitted since this is felt to be a matter of individual choice. Ingram (1948) has stressed the importance of using only simple or tried remedies and suggests suitable applications for common skin conditions. Wigley and Fox (1950) provide a list of " favourite prescriptions " for skin diseases with indications for their appropriate use ; and finally a useful account of the properties of some of the new emulsifying bases and other pharmaceutical aspects of local applications has been given by Payne (1950).

The nature of the hazard and the reasons for the investigation into the possible effects of repeatedly absorbing small quantities of formaldehyde were clearly explained to the radiologist and haematologist. They were of the opinion that there was nothing abnormal in this respect that could be attributed to the men's occupation, and the final results shown in the table seemed to indicate that there is no definite evidence of ill health which can confidently be associated with exposure to formaldehyde. In nine instances the men had lost weight since they had begun the job several years previously and two cases suffering from dyspnoea apparently developed this while working in the plants but one or more of several factors may have been responsible.

Most polymers are chemically inert and normally produce no pathological effects. They may however contain traces of free monomer which is often a highly active chemical substance capable of being an irritant like formaldehyde, a narcotic such as vinyl chloride, or a vesicant in the case of methyl chloracrylate. The monomer can be liberated from the polymer under certain conditions as, for example, during the machining of polymethyl methacrylate sheet when the fine powder can produce irritant effects like the monomer.

In addition plastic materials may contain other chemicals known to be toxic such as caustic soda (catalyst), tricresyl phosphate (plasticizer), lead carbonate (stabilizer) or cadmium compounds (pigment), and it is possible for those to bloom or leach out of the material. These chemicals can also be extracted under certain conditions by subjecting the plastic to a solvent such as an acid or an alkali.

Lastly some polymers under unusual conditions give rise to decomposition products which may have toxic effects ; an example of this is the fever produced by inhaling the fume of polytetrafluorethylene which has been heated to an abnormally high temperature (over 300°C.).

These facts, together with the increasing use of plastic materials for medical and surgical purposes or in connexion with foodstuffs, make it essential

for their toxicity to be given careful consideration. Some of their uses in surgery have already been described but a few examples are given below of the way in which they may come into contact with food and drink. Plastics for this purpose may be used in the form of (*a*) cups, beakers, plates, trays, bowls and other utensils ; (*b*) tubes for conveying consumable liquids, e.g. water, beer, etc.; (*c*) films for wrapping ; (*d*) linings for food containers, refrigerators, conveyor belts, and machines used in the manufacture of food.

Plastics used for the above purposes therefore should ideally contain no toxic substance of any kind although this may sometimes be difficult to ensure in practice. In all cases of doubt it is essential that the plastic and its ingredients should be subjected to most rigid physical, chemical, and physiological tests to ensure the absence of toxicity in applications of this kind.

SUMMARY

Synthetic plastic materials are made from polymerized chemicals with the addition of various other compounds.

Polymers can be divided into condensation and addition, or thermoplastic and thermosetting types.

The condensation polymers are typically represented by a group of formaldehyde products. The effects of formaldehyde on the skin and after absorption are discussed. Clinical examples and the incidence of dermatitis in one small factory are quoted. The result of an investigation on workers making formaldehyde products is described to support the contention that formaldehyde has little or no chronic effects when repeatedly absorbed in small quantities.

The nylon polymers are briefly mentioned.

The pathological effects of some addition polymers, their monomers and substances associated with their manufacture are discussed, including polythene, polyvinyl chloride, polymethacrylate, and polymethyl chloracrylate.

A brief reference is made to laminated plastics.

The importance of a full investigation of plastic materials likely to be used for certain purposes is stressed.

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APPENDIX

The following toxicological data were obtained from experiments carried out at the Industrial Hygiene Research Laboratories of Imperial Chemical Industries Limited.

(*a*) **Dinonyl / Dioctyl Phthalates.**—Each compound used separately gave the following results :—

Oral Administration.—No ill effects observed in

animals receiving doses by mouth up to 2·0 ml./kg. (1·97 g./kg.).

Inhalation.—No ill effects observed in rats exposed to air saturated with the vapour of the compound at 18° C. and 28° C. for 12 successive six-hour periods.

Skin Application.—The shaved rat skin remained normal after 10 applications (two applications of the neat material each day for five days). No ill effects were observed when it was applied to the skin of the human forearm twice daily for five days.

(*b*) **Methyl Alpha Chloracrylate.**—The toxicity is as follows :—

200 parts per million killed six rats after five hours' exposure.

100 parts per million killed six rats after six hours' exposure.

50 parts per million killed six rats after nine hours' exposure.

25 parts per million killed six rats after three six-hour exposures.

10 parts per million killed six rats after 30 to 84 hours' exposure.

Experiments with the vapour have shown that it is a highly toxic compound. Concentrations in air from 200 parts per million down to 10 parts per million caused death in rats from respiratory disorders after varying times of exposure.

Further experiments were carried out by human volunteers with the following results :

0·025% *v/v* (250 *p.p.m.*)—Immediate slight burning sensation in the eyes, followed by lachrymation, slight headache. Feeling of " tightness " over the eyes one hour later (total exposure 10 seconds).

0·005% *v/v* (50 *p.p.m*).—Lachrymation after about 10 seconds.

0·001% *v/v* (10 *p.p.m.*).—Very slight irritation of the eyes after 20 seconds.

0·0005% *v/v* (5 *p.p.m.*).—Very slight irritation of the eyes after 20 seconds.

These reactions were observed in three volunteers and were identical except that one volunteer did not experience headache at the concentration of 250 p.p.m.

It will be noted that all exposures were of short duration and that no difference was observed between 10 and 5 p.p.m. This may be different for longer exposure. In addition owing to previous experiments with rats showing the effects of 10 p.p.m. on the lungs, the volunteers did not inhale the vapours.

Effects on Human Skin.—Two drops of the neat material were applied to the inside skin of forearm. Burning sensation in 10 seconds. Quite painful after 20 seconds. Immediately washed off, washing kept up for five minutes. Slight erythema of treated area about size of a shilling. No pain. Twenty-four hours, painful to touch. Treated area, no increase in size. " Angry " red with pale centre (blistering). Forty-eight hours, definite blister, no pain and erythema much decreased. No treatment was applied but the area was kept clean.

(*c*) **Alpha Chloracrylic Acid.**—The acid, 5% w/v in water attacks the skin and eyes and can severely damage the latter. The acid neutralized with caustic soda (NaOH) to give a 5% sodium chloracrylate solution had no effect on rabbits' eyes and human skin.

Effects on Human Skin.—Of a 5% w/v aqueous solution of the acid, 0·5 ml., applied to human skin and allowed to dry caused a mild burning sensation and slight erythema after six minutes. The area was then washed with cold water. One hour later the erythema had increased and after two hours the treated area was very red and sensitive to touch. After 12 hours there was very little change, but after 24 hours the erythema was much reduced. No pain or sensitivity was present. After three days the skin was quite normal.

Rabbits' Eyes.—Two drops of the above solution placed in the conjunctival sac of a rabbit's eye caused immediate intense irritation. The animal kept its eye closed for about five minutes. When opened the eyelids were seen to be injected and after one hour they were oedematous. After two hours a whitish discharge appeared at the anterior corner of the eye. The pupil had contracted to about a third of normal size. Eyelids sealed with exudate. Twenty-four hours, no change. Forty-eight hours, no change. Seventy-two hours, the eye was half open and the oedema was somewhat lessened. The pupil was now about half size and reacted to light. Recovery was slow but no treatment had been applied.

Four drops of 5% sodium chloracrylate (aqueous acid solution neutralized with NaOH) (two at one-hour intervals) had no effects on rabbit's eyes ; 0·5 ml. applied to human skin (two at two-hour intervals) had no effect on human skin.

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AGE AND WORK*

A STUDY OF 489 MEN IN HEAVY INDUSTRY

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Of the numerous expressions of future demographic trends in Britain, none is more starkly realistic than the calculation of the Royal Commission on Population (1949) that :

> " The cost to the Exchequer of retirement pensions, making no allowance for any future fall in mortality, is estimated (at pension rates current in 1948) to increase from £238 millions in 1948 to £501 millions in 1978 ".

An extension of working life beyond the present conventional retiring age would both reduce national expenditure and increase national income, but if indeed " occupation is the best medicine " it would also achieve an immeasurable increase in health, happiness, and efficiency for old folk themselves.

Much has been said and written on the employment of old people. Reduced to its elements the problem is how to provide suitable work for those who are fit, willing and have, or can acquire, the necessary skills. It is important to remember that this problem does not arise only at or after the age of 65 years ; there is evidence that it begins some years earlier. Table 1 shows the percentage unemployment by age groups in June, 1950 (*Ministry of Labour Gazette*, June, 1951).

TABLE 1

AGE AND UNEMPLOYMENT IN BRITISH MALES, JUNE 1950

Age Group	Estimated Total No. of Employees	Nos. Registered as Wholly Unemployed	% Unemployed
15–20	1,290,000	15,780	1·2
21–40	6,226,000	67,635	1·1
41–50	3,018,000	38,208	1·3
51–55	1,117,000	22,503	2·0
56–64	1,563,000	45,839	2·9
Total	13,214,000	189,965	1·4

*This work was done in 1951 during the tenure of a full-time grant from the Medical Research Council.

The significant rise from the 40s onwards in the proportion of unemployed indicates that older people who have given up one job find increasing difficulty in obtaining another. From the social survey by Thomas and Osborne (1950) came the finding that the average age at retirement from full-time work of a fairly representative sample of men age 55 to 74 was 62 years. It may be concluded that the retention of older people in work is not solely a matter for attention at age 65.

Suitable Work

If older people are to be retained in or regained by industry their efficient employment depends upon the application of knowledge regarding what constitutes suitable work for them. The search for a definition of work appropriate to older people as a group consists basically of the discovery of changes with age in psycho-physiological function. Since the measurement of any human function is a measurement of range, such a definition must necessarily be a general one within which the problem of the suitability for work in a given individual will be solved by individual assessment.

In respect of age, this individual variation is of particular importance. Both experimental (Welford, 1951) and field research (Sheldon, 1948) have shown that with increase in age the average level of performance or activity tends to fall and the scatter round that average tends to increase. If this fundamental fact is ignored there is a danger that suitable work for older people may be too tightly defined in terms of the average with inevitable detriment to those individuals whose capacities lie well above or below that average.

Age and Skill

The experimental and field studies of the Nuffield Unit for Research into Ageing (Welford, 1951) have shown that as age increases there is a fall in

the ability, and perhaps also the inclination, to do work demanding high pressure for speed. It would seem that work in which piece-rate payments, or pacing by a machine or conveyor belt, force the worker to maintain rapid rates of performance is unsuitable for the majority of older people who prefer, indeed require, jobs where the rate of working is at least to some extent under their own control.

The second important indication reported by Welford is that skill is more easily acquired by younger people but once acquired is usually well maintained in the upper age groups. The industrial and experimental studies taken together indicate that learning difficulties on some types of operation appear as early as the 30s and that a major difficulty for older people lies in the comprehension of situations which are novel or confusing in " display ".

The practical implications of these findings are neither simple nor straightforward, first because *every* older individual does not exhibit the changes mentioned, and secondly because even those who do will not necessarily be employed on high speed work. From the industrial standpoint therefore the problem becomes one of detecting those individuals who in middle life show signs of strain, and either modifying the job to which they are accustomed or transferring them to new jobs which offer a lower tempo of work. Of these alternatives the first is the more desirable in view of the demonstration that older people tend to have more difficulty in mastering new skills.

Industrial Skill.—It is commonly believed that the lot of the older unskilled man is much less happy than that of his more skilled contemporary. Implicit in that view is the suggestion that by increasing the proportion of skilled young people the future problems of age and work will be correspondingly smaller. From a general socio-economic standpoint the need for more skilled workers is undoubted, but it is by no means certain that the problem of suitable work for older people would be solved by an all-round increase in the number of skilled workers.

In the social survey by Thomas and Osborne (1950) a comparison was made between the occupations of a sample of men aged 55–74 years and those of a sample of the male population aged 18 years and over. From the definitions provided, it can be assumed that " manipulative workers " correspond with the designation " skilled " and " operative " with " semiskilled ". The findings are shown in Table 2.

TABLE 2

PROPORTIONAL DISTRIBUTION OF OCCUPATIONS IN TWO MALE SAMPLES (Thomas and Osborne, 1950)

Occupation	Men Aged 55–74 (%)	Men Aged 18 and Over (%)
Professional and technical ..	5	5
Managerial	27	20
Clerical	7	5
Manipulative (skilled)	14	20
Operatives (semiskilled)	25	35
Unskilled	22	15
Size of sample	1,274 (100%)	3,686 (100%)

For the higher proportion of older men in managerial posts promotion is the likely explanation. The interesting points are the smaller proportion of older men in the skilled and semi-skilled groups and the higher proportion in the unskilled group; these differences suggest that a number of men in the upper age groups have moved to less skilled work. The terms " unskilled ", " skilled ", and " semiskilled " must include a wide range of jobs and the explanation of this move to unskilled work may lie in the nature of a few selected tasks embraced by them rather than in some feature of skill as a whole, but the figures show the need for caution when relating level of industrial skill to the problem of suitability for work at older ages.

Alongside this observation must be set two further findings from the same social survey. Among the 55–74 age group the incidence of long-term unemployment since age 45 was 26% in the unskilled compared with 11% in the skilled group. In this respect the possession of skill was an advantage, but when a sample of employers was asked what weight they would attach to skill when engaging new workers over 45 years of age, it appeared that an older skilled worker had only a slightly better chance of employment than an unskilled worker over that age.

Despite the strong belief that skilled workers encounter fewer problems as age advances, there appear to be grounds for suspecting that they do in fact meet difficulties. The adjective " skilled " however refers only to one aspect of an industrial task; it is possible that two tasks of similar complexity in skill may require very different amounts of effort for their execution and, should a move off the heavier task be made on grounds of fitness, the change may be mistakenly associated with the skill or vice versa.

Age and Fitness

> "It must be frankly admitted that so far no reliable standard of measurement of fitness has been evolved. Many attempts have been made to assess this elusive yet recognizable quality. Physical fitness depends on a collection of qualities, psychological as well as physiological, and it is extremely difficult to determine which combination is likely to give the truest index" (Cathcart, Hughes, and Chalmers, 1935).

Despite intensive research the quantitative assessment of fitness is still a complex and controversial problem. A discussion of the validity of the various indices of fitness is outside the scope of this paper, but it is appropriate to note that there appears to be a lack of general agreement on how far the results of the many tests of fitness correlate with general or particular efficiency for real life tasks. The resemblance between the two kinds of work—work performed in a test and in industry—is usually slight, especially in regard to duration and distribution of effort; even the simplest manual labour in industry may vary widely in the timing and nature of its demands on the labourer.

No claim is made that the facts here presented are a complete distillate of the extensive research literature on fitness but those which are cited appear to indicate the general trend with age in certain important functions.

Tests of Fitness.—The findings from several investigations into changes with age in muscle strength have been reported (Cathcart and others, 1935; Simonson, 1947; Cullumbine, Bibile, Wikramanayake, and Watson, 1950). The general trend revealed is a peak in the 20s and 30s followed by a gradual decline to about 80% of peak values in the 50s and 60s. These studies reveal nothing to suggest that older people are unable to do work in which occasional strenuous lifting or gripping is required but such tests do no more than measure an isolated local ability.

A variety of cardio-respiratory indices have been measured by exercise response tests, and from those in which age has been studied as a major variable the general trend is similar (Robinson, 1938; Simonson, 1947; Shock, 1947; Cullumbine and others, 1950; Hugh-Jones, 1952). With increasing age the physiological reserves become reduced, the capacity to respond to and recover from exercise is lowered, and the physiological cost of work becomes greater. Fitness as measured by these various indices is therefore reduced but it needs to be stressed that the change as expressed in terms of an age-group average is gradual and that many older people are well above or below that average.

It is permissible to infer from these test results that rest pauses should be more frequent for older people and that they should be allowed a rather lower level of working effort. Such conclusions do not really tell industry any more than it already knows. They do, however, serve to emphasize the urgent need for accurate knowledge of the physical demands of different kinds of industrial work. Until that knowledge is available the relation between fitness for laboratory test-work and real-life work will continue to be uncertain.

Training.—It is well known that training can improve performance on tasks requiring strenuous work. Crowden (1928) and Robinson (1938) have given convincing demonstrations of the economy of energy expenditure which can be achieved by trained practice, and it would seem reasonable to suppose that other things being equal those older men whose lives have mainly been spent on heavy work are likely to be more physically fit for active work than those accustomed to more sedentary occupations.

Lastly it is right that the importance of the individual's place in the group should be reiterated. Since the placing in suitable work of older people eventually comes down to an individual problem, it is earnestly to be hoped that simple, reliable tests of fitness can be evolved, from the results of which accurate individual guidance can be given to those whose further employment presents difficulty on grounds of fitness.

Age and Motivation

How much a man is willing to do and interested in doing may obviously vary with age. The scientific study of motivation is only beginning (Bartlett, 1951a) and where facts are few opinions are many. In the industrial world, where much of the work done offers little opportunity for satisfaction, it is perhaps not surprising that many older men show little inclination to work beyond the age at which pensions become payable.

A succession of speculations on the attitude of older people to work can serve no useful purpose, but it would be unfair to omit reference to the widespread belief that older people do in general display in greater measure such virtues as carefulness and responsibility. How valuable these may be to an employer has been described by Richardson (1953).

Although the effects of age on motivation are as yet uncertain, there is no doubt that in real life attitude to work is as essential a factor in the consideration of employment of older people as

are skill and fitness. Indeed none of these three can be thought of or studied in isolation from the others. The truth of that contention can be exemplified in many industrial jobs ; for example, an ironmoulder paid by piece rates has to perform skilled work at a rapid tempo demanding a high level of energy expenditure. As he comes nearer to the age of 65 his cerebral mechanism controlling skill and/or his physiological mechanism controlling effort may decline and his reduced family commitments may lower his interest in and willingness for his job ; should he seek a change of work, it would be difficult to say how far each variable was responsible.

Age and Industry

It is evident that a definition of suitable work for older people is still very incomplete. Industry has always encountered the problem of age and work, and its solution has varied according to economic circumstances ; there are welcome signs that the more enlightened firms are beginning to tackle the problem with a view to adjusting their production to an ageing labour force.

The nature of the problem varies. In many lighter industries the difficulty for older people lies in the realm of skill, whereas in heavier industries decline with age in fitness assumes greater importance. The simple fact that British economic stability rests mainly on its heaviest industries—coal, iron, and steel—makes the necessity for knowledge of the relation between age and heavy work an urgent one.

Heavy Work.—Since there is no clear cut definition of heavy work it is not easy to study its relationship to age. It is often claimed that heavy industry cannot employ many older men but some recent evidence suggests that this is by no means an accurate statement. The Industrial Welfare Society's Report (1950) on 400 of its member firms showed that whereas the number of men over 65 years of age expressed as a proportion of all men employed by these firms was 2·7%, the proportion in two heavy industries—tin and sheet steel—was 4·7%. In a survey of the age distribution of 110,000 men employed by 42 firms in the iron and steel industry Fleming (1952) found that the average proportion of the labour force aged 65 years and over was 4%, with a range from 0·7% to 11·3%. These observations reveal the need for caution when speaking of the connexion between age and heavy industry.

There is little information on older people and heavy jobs. Belbin and Sewell (1950) studied age distributions on a number of industrial operations included among which were " . . . operations involving considerable muscular effort in the handling of heavy materials and operations involving a degree of activity which made them regarded as heavy in the factories concerned ". They reached the conclusion that many heavy jobs are carried out by older people, especially when time rates are paid or where the effort is intermittent and the speed at which the work is performed can be regulated by the individual. On jobs which required continuous heavy exertion few older men were found and definite evidence was obtained of moves off these jobs between the age of 50 and 60.

Industrialists, and especially industrial physicians, are familiar with the problems raised by moves off heavy work by older men. The provision of alternative work is often difficult and men may be forced to retire simply because suitable work is not available. If to the effect of age is added some disability the plight of the older workmen is an unhappy one. In a follow-up study of the return to work of male hospital patients aged 50–64 years, Pemberton and Smith (1949) found that those who had been employed in the coal-mining and steel industries had severe difficulty in obtaining work suited to their capacity.

The Present Investigation

The study here reported was designed to explore the answers to four questions relevant to the relation between age and heavy work : (1) Are older men doing less heavy work than younger men ? (2) At what age do men move to less heavy work ? (3) With what factors are these moves associated ? (4) What is the state of health of older men in heavy industry ?

The first problem was how to obtain access to the information sought. Personal interview was chosen as the method most likely to yield results of value, and it was therefore necessary to find a group or groups of men which would satisfy several requirements : (1) They should be reasonably concentrated. (2) They should be employed or have been employed in industries where a high proportion of heavy jobs was likely. (3) They should contain a substantial proportion of older men.

For a complete investigation it was necessary to draw samples from employed, unemployed, and retired men in each age-range. The difficulties encountered in the attempt to achieve completeness were so formidable that the last two categories had to be omitted ; the study therefore was concentrated on men at work, though it was realized

that by so doing an uncertain amount of its value would be sacrificed.

Eventually the three stated requirements were met in two iron-foundries and a coal-mine.

The Interviews.—An essential first step was definition of the lower limit of the age-range within which men were to be interviewed. Some of my previous experience as an industrial medical officer suggested that men aged 50 years and over would provide the required data; this limit was also satisfactory in that from the age distributions of both foundries and coal-mine it appeared likely to yield a sufficient number of men for interview in one complete year.

Accordingly only men aged 50 years or more as recorded (at the place of work) on their last birthday were asked to come for interview during working hours.

The scope and content of the interviews were as follows :—

Health.—Questions covered the subjects' past and present health.

Past.—This included the date, duration, and nature of all injuries and illnesses causing absence from work for one month or more at any time.

Present.—To the question, "What is your present state of health?" the actual replies were recorded, thus providing self-assessments of health. The presence of any symptoms or disabilities was noted and whether medical attention was being received.

Job Changes on Health Grounds.—Subjects were questioned concerning any change of job dictated by health.

Occupation.—Again the past and present were covered.

Past.—Each man was asked what kind of work he had done since age 20. The class of work was sought rather than a detailed description of every job; questions were devised to ascertain the level of skill, physical effort, the duration of each job, and whether and for what reason a move to less heavy work had been made.

Present.—Facts similar to those above were obtained for the job at the time of interview, but special encouragement was given to each man to assess the heaviness of his job and its general suitability in relation to his age.

As soon as possible after the interview a visit was paid to each man's place of work. Observation of the job in progress together with the opinion of workmen and supervisors made it possible to place each job in one of three grades of physical effort.

The Study Material.—The study material was found in two foundries and a coal mine.

Large Foundry.—In the large foundry a variety of solid fuel cooking and heating stoves was produced in two main stages, by making components in the foundry, and their assembly in the factory.

In both sections of the works much handling of components was necessary and in general the level of physical effort was considerable.

The firm was long established with strong local traditions; it lay on the edge of an industrial area in which foundries, brick works. and coal-mines were the chief places of employment. A total of 879 male non-staff weekly wage-earners was employed, and of these 244 (28%) were aged 50 years and over; 223 were interviewed the other 21 being accounted for as follows :

Refused interview	1
Sickness absence throughout period of study	6
Left the firm before interview arranged	7
Severe stutter	1
Deaf mute	1
Constant night-shift	5

The managerial policy for older non-staff workers was one of active encouragement to remain at work until age 70 when, with the occasional exception of a highly skilled tradesman, all workers were retired, a small non-contributory pension being paid.

Small Foundry.—The small foundry was located one mile from the first foundry, the products and methods of manufacture being similar. Also long established, this foundry employed a total of 324 male non-staff weekly wage-earners of whom 68 (21%) were aged 50 or over; 66 were interviewed, one man having left before his interview was due and one being absent through illness.

A small non-contributory pension was paid to retired workers but no age-limit was put on those who were fit and willing to do useful work.

The Coal-mine.—One of the largest in Scotland, it employed 1,450 men and had been in production for 30 years. By comparison with other pits, it had been little affected by economic vicissitudes and was reckoned to have a fairly stable labour force.

Three hundred and thirty-nine men (22%) were listed as being aged 50 years or over and of these 200 were interviewed. Whereas in the foundries no serious obstacles were encountered in obtaining a 90% sample for interview, access to about one-third of the miners was either impossible or so difficult for occupational reasons, shift work, location of faces and headings, etc., that the attempt to obtain a truly representative sample had to be abandoned.

Eventually a simple selection procedure was adopted. From a list of dates of birth, men aged 50 years and over were asked in sequence to come for interview; if available and willing (there were two refusals) they were seen. At least 43 men were not available through sickness absence and 12 had left to work elsewhere before their names were reached.

The colliery manager held the view that since no rigid age for retirement was laid down (the miners' pension scheme was not then in operation) older men should be encouraged to remain at work so long as they retained a useful capacity for work.

Findings

"Work Heaviness"—Using the opinions of workers, supervisors, and the investigator, each man's job at the time of interview was graded as heavy, medium, or light. The distinction between these categories is blurred and they can more correctly be regarded as three overlapping parts of a range. The inevitable error in so subjective a grouping was to some extent reduced by the small number of defined occupations within which variation could occur.

Table 3 shows the distribution of "work-heaviness" in each of the three industrial units.

There is a fall from the 50s through the 60s to the 70s in the proportion of men on heavy work but only in the data from the coal-mine is the difference significant at the conventional level. It is, however, necessary to consider the absolute numbers from which these proportions are derived; between each decade of age there is a sharp drop in the numbers at work due to the combined effect, if the study were a "continuous" one, of death, illness, and retirement. (The assumption is made that losses due to men leaving to seek work elsewhere are balanced by gains from moves in the opposite direction.) If these factors or any one of them operated selectively on men in the heavy grade of work at a given age, then clearly the older "work heaviness" distribution would show a decline in the proportion of men on heavy work. Scrutiny of the absolute figures provides only one clue to the contrary, the *increase* from 15 men aged 50–59 to 25 men aged 60–69 in the light work column of the coal-mine data. This could only be due to a redistribution of "work heaviness" between these ages. Therefore an explanation of the findings in Table 3 requires analysis of the occupational histories for evidence of moves to less heavy work.

Moves to Less Heavy Work.—It was seldom difficult to reconcile admitted moves to less heavy work with the evidence from the work history but to be content with admitted changes only would have ignored many obvious discrepancies in the past work record. Such changes as enumerated in the subsequent tables include therefore both admitted and unadmitted moves to less heavy work.

Individuals were placed in one of two groups. Group I contains those men in whose history there was no detectable evidence of a move to lighter work. Group II contains those who had transferred to lighter work. One possible source of error must be mentioned; there seemed to be an accepted tradition that older men should "ease up", this being expressed in such phrases as "I don't get the heaviest tasks now" and "I'm allowed to take my own time". While confirmation of this was sometimes obtained, such ill-defined changes were not classed as changes to lighter work.

TABLE 3

WORK DISTRIBUTION BY AGE GROUPS

Age at Interview (years)	Small Foundry				Large Foundry				Coal-mine				Total Interviewed
	Work				Work				Work				
	H	M	L	Total	H	M	L	Total	H	M	L	Total	
50–59	6 (15%)	22 (53%)	13 (32%)	41 (100%)	41 (31%)	64 (49%)	27 (20%)	132 (100%)	73 (60%)	33 (27%)	15 (13%)	121 (100%)	294
60–69	1 (5%)	16 (76%)	4 (19%)	21 (100%)	16 (19%)	41 (49%)	27 (32%)	84 (100%)	17 (26%)	24 (36%)	25 (38%)	66 (100%)	171
70–79	—	2 (50%)	2 (50%)	4 (100%)	—	4 (57%)	3 (43%)	7 (100%)	1 (8%)	7 (54%)	5 (38%)	13 (100%)	24
All ages	7 (12%)	40 (60%)	19 (28%)	66 (100%)	57 (25%)	109 (49%)	57 (25%)	223 (100%)	91 (45%)	64 (32%)	45 (23%)	200 (100%)	489

H = Heavy M = Medium L = Light

Small foundry: n = 4 χ^2 = 4·41 P greater than 0·30
Large foundry: n = 4 χ^2 = 8·44 P greater than 0·05
Coal-mine: n = 4 χ^2 = 32·58 P less than 0·01

TABLE 4
INCIDENCE OF CHANGE TO LIGHTER WORK IN AGE-GROUPS

Age at Interview	Small Foundry			Large Foundry			Coal-mine		
	Group I	Group II	Total	Group I	Group II	Total	Group I	Group II	Total
50–59	16 (39%)	25 (61%)	41 (100%)	68 (52%)	64 (48%)	132 (100%)	56 (46%)	65 (54%)	121 (100%)
60–69	8 (38%)	13 (62%)	21 (100%)	23 (27%)	61 (73%)	84 (100%)	13 (20%)	53 (80%)	66 (100%)
70–79	1 (25%)	3 (75%)	4 (100%)	3 (43%)	4 (57%)	7 (100%)	—	13 (100%)	13 (100%)
Totals	25 (38%)	41 (62%)	66 (100%)	94 (42%)	129 (58%)	223 (100%)	69 (34·5%)	131 (65·5%)	200 (100%)

Group I = no change. Group II = change.

Small foundry : n = 2 χ^2 = 0·31 P greater than 0·80
Large foundry : n = 2 χ^2 = 12·26 P less than 0·01
Coal-mine : n = 2 χ^2 = 20·68 P less than 0·01

Table 4 shows the distribution of the two groups.

No significance can be attached to the figures from the small foundry, but in the large foundry and the coal-mine there is a sharp increase from the 50s to the 60s in the proportion of men who had transferred to lighter work. In the coal-mine data, the trend continues through to the 70s ; the change of trend in the 70s in the large foundry may be chance variation, but is more probably due to the " selection by skill " policy operated beyond the age of 70 in that firm.

One possible explanation of the difference in Table 4 between the 50s and 60s is that as a group the latter might in the past have been employed on heavier work than those 10 years younger, and could therefore be expected to show a higher rate of transfer at the same age. To assess this source of error in interpretation a comparison is made in Table 5 between the pre-transfer work of the two age-groups.

There are no significant differences between the two age-groups in respect of their " work heaviness " before transfer ; the rise with age in the proportion of men in Group II (Table 4) must be otherwise explained.

The second possibility is that comparability between the age groups has been disturbed by the factors adduced above. In Table 4 from the 50s to the 60s (assuming that the observed differences would appear in a continuous study) the absolute numbers of men at work in the small foundry, large foundry, and coal-mine drop by 20, 48, and 55 respectively. If the cause of these differences, death, moribidity, unemployment (including retirement), were selectively influencing Group I men in the 50s, then without further transfer the observed variation in proportions could be accounted for.

Evidence will later be led to show that changes to lighter work were taking place at all ages, and therefore it can be concluded that the increase from the 50s to the 60s in the proportion of men who had changed to lighter work is the result of two events, losses from the labour force and transfers within the labour force.

Skill and Transfer to Lighter Work.—In view of the common belief that skilled older men encounter fewer problems than those less skilled, it seemed worthwhile to examine the relation between the level of industrial skill and the

TABLE 5
" WORK HEAVINESS " OF GROUP II MEN BEFORE TRANSFERENCE TO LIGHTER WORK

Age at Interview	" Work Heaviness " before Transference to Lighter Work								
	Small Foundry			Large Foundry			Coal-mine		
	H	M	L	H	M	L	H	M	L
50–59	17 (68%)	8 (32%)	—	48 (75%)	16 (25%)	—	63 (97%)	2 (3%)	—
60–69	10 (77%)	3 (23%)	—	49 (80%)	12 (20%)	—	52 (98%)	1 (2%)	—
	S.E. of difference between 68% and 77% = 15·5%			S.E. of difference between 75% and 80% = 7·4%			S.E. of difference between 97% and 98% = 2·9%		

H = Heavy. M = Medium. L = Light.

TABLE 6

SKILL DISTRIBUTION BY AGE OF MEN NOT TRANSFERRED TO LIGHTER WORK (GROUP I) IN FOUNDRIES ONLY

Age at Interview	Skilled	Semiskilled	Unskilled	Totals
50–59	41 (49%)	25 (30%)	18 (21%)	84 (100%)
60–69	19 (61%)	7 (23%)	5 (16%)	31 (100%)
70–79	4 (100%)	—	—	4 (100%)
Totals	64 (54%)	32 (27%)	23 (19%)	119 (100%)

$\chi^2 = 4{\cdot}98$ $n = 4$ p = greater than 0·20

incidence of change to lighter work. The coal miners proved extremely difficult to grade, there being no clear distinction between one level of skill and the next; they are therefore excluded from numerical consideration though, as will be discussed later, there was some evidence that the pattern of skill and age was similar to that shown below for the foundries. Grading of skill was based on length of training, recognition by trade unions, wage rates and "status". With the help of supervisors each man was placed in the appropriate group, and, since the range of jobs was very similar in the two foundries, the data from them have been combined in Tables 6 and 7.

Chance fluctuation may be responsible for the observed differences with age in proportions (Table 6) but if the effect of age is real a twofold explanation is likely. The absolute numbers reveal that the losses between the 50s and the 60s are relatively greater in the semi-skilled (18 out of 25) and unskilled (13 out of 18) groups than in the skilled group (22 out of 41); these losses may have been either through transfer to Group II or through the several factors already referred to which operated to remove men from the labour force.

Inasmuch as the reduction from the 50s to the 60s is relatively lighter in the skilled group, the latter is more fortunate but consideration of the facts from Group II indicates that at least one important group of skilled men had encountered difficulties. Table 7 shows the skills distribution before and after transfer to lighter work.

In the age groups 50–59 and 60–69, the observed difference between the pre- and post-transference proportions of skilled men is three times the standard error. This significant difference permits the conclusion that a change to lighter work was frequently associated with a reduction in skill.

The reason for this strong correlation between moves to less heavy work and drop in skill is to be found in the nature of one of the main occupations in these foundries, ironmoulding. There were three fairly distinct grades of moulder; all merited the title "skilled" in the sense that a full apprenticeship was required for entry but in the two higher grades the speed of work was lower, the accuracy demanded was higher, and time-rates were paid. The majority of moulders were employed in the third grade where the tempo of work was rapid and piece-rates paid. Some exchange between grades took place, but men employed for many years in the lowest grade seldom attempted or were encouraged to attempt re-mastery of the higher skills; when a move to less heavy work was made, it was usually away from iron-moulding, a trend which largely accounts for the figures in Table 7.

TABLE 7

DISTRIBUTION OF SKILL BEFORE AND AFTER CHANGE TO LIGHTER WORK BY AGE GROUPS (COMBINED DATA FROM FOUNDRIES)

Age at Interview	Group II before Transfer to Lighter Work				Group II after Transfer to Lighter Work			
	S	SS	US	Total	S	SS	US	Total
50–59	51 (57%)	23 (25%)	16 (18%)	90 (100%)	25 (28%)	15 (17%)	50 (55%)	90 (100%)
60–69	40 (55%)	18 (25%)	15 (20%)	73 (100%)	15 (20%)	8 (11%)	50 (69%)	73 (100%)
70–79	5 (71%)	2 (29%)	—	7 (100%)	1 (14%)	3 (43%)	3 (43%)	7 (100%)
Totals	96 (57%)	43 (25%)	31 (18%)	170 (100%)	41 (24%)	26 (15%)	103 (61%)	170 (100%)

S = Skilled. SS = Semiskilled. US = Unskilled.

Age 50–59: standard error of difference between 57% and 28% = 9·9.

Age 60–69: standard error of difference between 55% and 20% = 10·5.

Age 70–79: standard error of difference between 71% and 14% = 30·2.

Age at Transfer.—A few men had obvious difficulty in remembering dates, and in such cases the most that could usually be achieved was to narrow the date down to a particular age-decade, if the change was early in working life or to a five-year period if it was more recent. It is very probable that some early job changes were forgotten, but that very few of these would rank as transfers to lighter work was suggested by the replies of a number of foremen and supervisors to questions on how often men in the 20s and 30s sought less heavy work. At these ages such requests were rare, and, therefore, although

the number of such recorded transfers in the early decades may be a slight under-estimate, this is not reckoned to be a serious source of error.

In presenting the findings account has been taken of the fact that the maximum age at change to lighter work was determined by the age at interview. Table 8 shows the crude relationship between the two ages.

There were five men in whose histories two separate permanent changes to lighter work were recorded ; to avoid confusion only the earlier of each pair has been included. It is seen that in general, the older the men were at interview the later had they changed to lighter work. It is safe to assume that this relationship is partly the result of a process of selection ; many of the men changing to lighter work in the 40s and 50s would be unfit or unwilling to continue at work, and their more able contemporaries who reached the 60s before transferring to less heavy tasks would inevitably show a higher mean age at the time of their move, the 70s repeating the pattern at a still higher average age.

To determine the true relation between age and transference to lighter work within the limits imposed by this selection effect, tables have been constructed to show, for each of the three industrial units, the rate of transfer at different ages. This rate was calculated by dividing the number of changes to lighter work by the total number at risk in each age period and then reducing the resulting figure to a rate per year. The number at risk during any given period comprised all those who had not previously changed to lighter work, and the tables therefore cover all men interviewed.

Tables A, B, and C, in the appendix, set out the results of this analysis.

In each age-group in each industrial grouping there is a distinct trend in the pattern of transfer to lighter work ; the rate rises from a low level in the 20s and 30s, becoming higher as the theoretical maximum age is approached. The curves are shown in Fig. 1 (overleaf).

The similarity between the curves suggests the operation of some common factor from about the age of 40 onwards, and it is now necessary to construct a hypothesis to explain these findings. We must consider the effect upon these curves which would result from the inclusion of two groups of men similar in age composition to those interviewed and formerly employed in the same industries but who had either retired, become unemployed, died, or were otherwise inaccessible at the time of study. It is again assumed that men going out to lighter work elsewhere were balanced by those coming in to lighter work.

The first of these two groups comprises men who had not changed to lighter work before giving up employment ; including these men in the data would raise the number at risk (n) in each age period up to the time of their retirement (or unemployment) without affecting the number of changes, and thus the rate of change would at first be lowered but their retirement would reduce the number at risk thereby producing a sharp rise in the rate. The effect would be to steepen the curves shown in Fig. 1.

The second group to be considered consists of men who changed to lighter work and continued on it for a period and then retired. Their addition

TABLE 8

NUMBERS OF MEN CHANGING TO LIGHTER WORK AT EACH AGE BY AGE-GROUPS AT TIME OF INTERVIEW

Age at Transfer	Age at Interview																		Totals
	50–54			55–59			60–64			65–69			70–74			75–79			
	SF	LF	CM	SF	LF	CM	SF	LF	CM	SF	LF	CM	SF	LF	CM	SF	LF	CM	
20–29	—	1	—	1	1	—	—	1	1	—	—	—	—	—	—	—	—	—	5
30–39	—	5	4	—	2	—	—	5	—	2	1	—	—	—	—	—	1	—	20
40–49	7	19	19	1	7	7	2	6	3	—	3	1	—	—	1	—	—	—	76
50–54	5	10	9	4	9	16	—	5	3	1	3	2	1	—	1	—	—	—	69
55–59	—	—	—	7	10	10	1	8	15	2	8	3	—	1	2	—	1	1	69
60–64	—	—	—	—	—	—	3	6	7	1	8	10	1	1	1	—	—	—	38
65–69	—	—	—	—	—	—	—	—	—	1	7	8	—	—	4	—	—	—	20
70–74	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2	—	—	1	4
75–79	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

SF = Small Foundry. LF = Large Foundry. CM = Coal-mine.

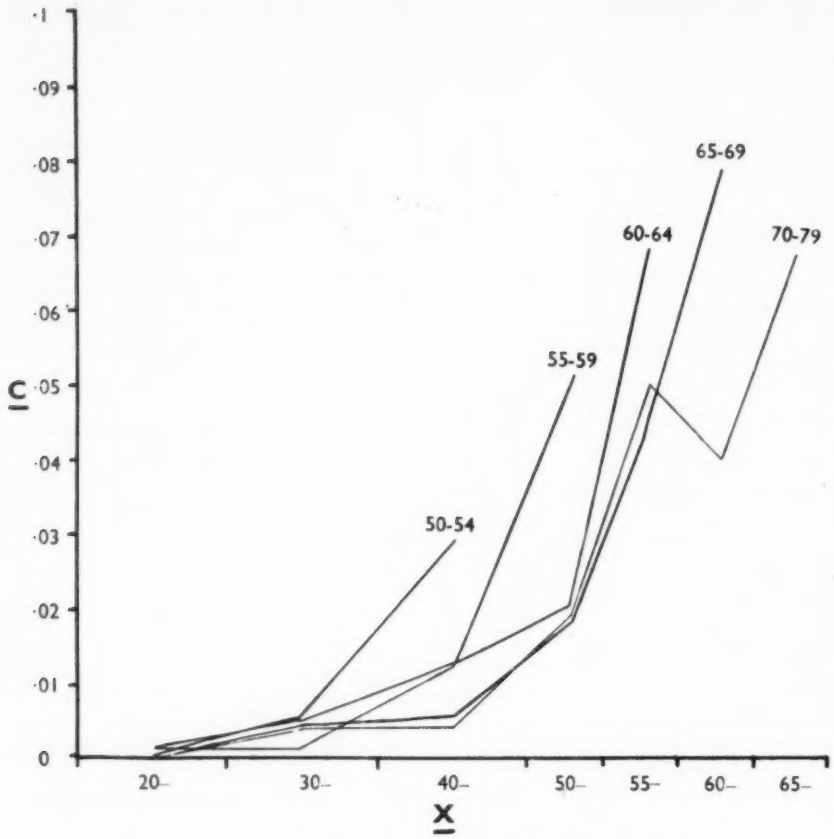

FIG. 1.—Graph of rates of transfer to lighter work by age-groups.
c = rate of transfer. x = age-periods at transfer.

to the data would raise the rate of such change at each age in proportion to the size of their contribution thereby raising the level of the curve and perhaps also inclining it more sharply.

Accurate prediction of the true rate of change is impossible without precise information on these two groups of men not covered by this study. It has, however, already been noted that national unemployment figures show a sharp increase from the 40s onwards and that the average age at retirement from full-time work is a few years earlier than age 65. If these observations are relevant to the groups under discussion, they lend some support to the tentative conclusion that the real trend of transference to lighter work is a low incidence until the 40s and a rapid rise from then on.

The Aetiology of Change to Lighter Work.—Several factors, notably the role of illness and injury, must be considered.

The Role of Illness and Injury.—Sixty-two per cent. of the men who had moved to less heavy work declared that an illness or injury was responsible. The proportions in the three industrial groups are shown in Table 9.

Doctors are familiar with the tendency to implicate health when a change of work is sought; with this in mind every claim that a change to lighter work had been on health grounds was examined at interview and accepted only if either the medical diagnosis or an adequate description of the ailment was forthcoming.

The nature of the illness or injury varied from trivial to severe. There were cases in which the need for a change of work had been indisputable on grounds of major disability but an interesting and not uncommon type of history was that of a move off heavy work following a minor injury or illness from which recovery had been both rapid and complete. It seemed that many men carried on in heavy work under increasing strain until a "trigger-factor" such as illness or injury supervened and the decision to change to lighter work was made. Some of the histories strongly suggested that the influence of work-mates, family, or medical adviser was important in reaching that decision.

Other Factors.—At interview it was often clear that for reasons of prestige, men were anxious

TABLE 9

Group	Small Foundry	Large Foundry	Coal-mine	Total
Proportion of moves associated with illness or injury	26 out of 41 (63%)	73 out of 129 (57%)	84 out of 131 (64%)	183 out of 301 (62%)

Standard error of 62% { in samples of 41 = 7·8%; in samples of 129 = 4·3%; in samples of 131 = 4·2%

to justify their move from heavy work and were inclined to invoke rather specious factors. The use of such expressions as " strain ", " my age ", " shortness of breath ", " fatigue ", was common but one point clearly emerged, the actual move to less heavy work was often preceded by a period of weeks or months during which the individual became increasingly aware of the heaviness of his work. What finally decided the request for a lightening of effort was obscure but an occasional clue was obtained. The sudden death or illness of a fellow heavy worker was mentioned by seven men as having decided them to seek lighter work " before the same thing happens to me ". Twenty-five miners stated that following the close-down of their former colliery they had not resumed heavy work. The falling vacant of a job where the duties were known to be light was given as the deciding factor by five men.

There appeared to be a similarity about the pattern of change whether this had followed illness or not ; a preliminary period of mounting awareness of the demands of heavy work, the actual move being determined by an event such as illness, injury, redundancy, or some external reminder of the supposed effects of age. The frequency with which " my age " was invoked to explain such a change in whole or in part was striking ; to many it was apparently an explanation which satisfied them and if this conventional belief is as strongly entrenched elsewhere as it was in these groups, it will be no easy task to alter it.

Speed of Work.—All men, whether they had changed to lighter work or not, were invited to mention any features of their work which had caused difficulty as they grew older. The outstanding reply was about the effect of speed.

In the foundries two main groups of men, ironmoulders and stove-fitters, were paid by individual piece-rates. The moulders worked in pairs in order to assist each other with heavy lifts and as far as possible men of about the same age were selected as " neighbours ". This arrangement worked well enough on the whole but of the 58 moulders who had changed to lighter work, five gave as their reason the strain of trying to keep up with the faster pace set by young " neighbours ". But even when the moulders were evenly matched for speed, the rate of work necessary to maintain earnings was high, and since the work was strenuous at each phase of the cycle, ironmoulding was one of the heaviest jobs in the factory. The moulders were almost unanimous that with increasing age the continuity of piece-work imposed greater strain upon them and they had no hesitation in defining suitable work as that which allowed the moulder to regulate his own speed of work.

Seventeen stove-fitters who had moved off piece-work were interviewed ; though less strenuous than moulding the rate of work was also rapid. Some years previously the stove-fitters had worked in small groups, the piece-rate earnings being calculated on the group output. Four of the fitters interviewed had given up that system of piece-work, and it later transpired that these four had been moved at the request of the other and younger members of the group who complained that they were too old (all four were in the late 50s) to keep pace and were therefore hindering the earning capacity of the group.

From the interviews with miners the effect of speed was again evident. To reach the coalface or rock heading a walk of one mile from pit bottom was necessary (personal experience on some 20 occasions confirmed the strenuous nature of this task). The main cause of difficulty for the older men was not the distance so much as the pace at which it had to be covered if they were to keep up with the younger men in the group. " At my job I'm all right " was repeatedly heard at interview, and was confirmed by visits to the coal-face where men in the late 50s who complained of marked shortness of breath on the hill up to the pit and on the way to the coalface could be seen stripping coal without visible distress. The reason appeared to be that at the coal seams rest pauses were largely under the individual's own control as they were on lone journeys to and from work.

Indeed the most important component of " light " or " lighter " work, as these terms were used by the men interviewed, was this opportunity to control the pace of work and the distribution of rest pauses. With the classification of " work heaviness " used in this study, it will be seen in Table 3 that relatively few men's jobs were classed as " light " yet the proportion of changes to lighter work was 50% or more ; it is important to emphasize that men often moved to lighter work yet still remained in the moderate category or even (in a few cases) in the heavy category. Provided the effort was broken up by rest pauses, the intensity of effort seemed of secondary importance.

Age and Health.—It seemed worthwhile to attempt a crude division of the men interviewed into health categories, first to observe whether the distributions varied with age and secondly to see what kind of relation lay between health and work.

TABLE 10
HEALTH CATEGORY BY AGE GROUPS BOTH FOUNDRIES)

Age at Interview	Health Category			Totals (100%)
	A	B	C	
50–54	67 (70%)	28 (29%)	1 (1%)	96
55–59	49 (64%)	21 (27%)	7 (9%)	77
60–64	30 (52%)	24 (41%)	4 (7%)	58
65–69	31 (66%)	13 (28%)	3 (6%)	47
70+	7 (64%)	3 (27%)	1 (9%)	11
Totals	184 (64%)	89 (31%)	16 (5%)	289

$\chi^2 = 10{\cdot}31$ n = 8 P = 0·20
A = good B = intermediate C = poor

The assessments used were based on the account of past and present health, supplemented where possible by personal observation during interview. From the tabulated replies men were assigned to one of three categories :

Category A : Good Health.—Criteria were no past illness or injury affecting present health ; unqualified statement that present health satisfactory ; not receiving medical attention ; no symptoms or disabilities.

Category C : Poor Health.—Criteria were history of past illness or injury affecting present health ; present health stated to be other than good ; recent medical attention ; presence of substantial disability restricting capacity for effort.

Category B : Intermediate.—Criteria were general health good ; presence of local disability. (The presence of a minor temporary ailment such as a cold was ignored.)

TABLE 11
HEALTH CATEGORY BY AGE GROUPS IN THE COAL-MINE

Age at Interview	Health Category			Totals (100%)
	A	B	C	
50–54	49 (74%)	14 (22%)	3 (4%)	66
55–59	31 (56%)	22 (40%)	2 (4%)	55
60–64	17 (44%)	20 (51%)	2 (5%)	39
65–69	17 (63%)	10 (37%)	—	27
70+	13 (100%)	—	—	13
Totals	127 (63·5%)	66 (33%)	7 (3·5%)	200

$\chi^2 = 20{\cdot}53$ n = 8 P = 0·01

The majority of assessments were easily categorized ; with those who lay near the borderline between categories some difficulty was inevitable, but from the outset it was recognized that consistent assignment was of the utmost importance if even broad conclusions were to be drawn. No conscious consideration of the work being done was taken into account and allowance for age was left to the individual. The assessments were checked on three occasions at intervals of several months and it was found on each recheck that 94% were consistent.

Tables 10 and 11 show the distributions by age.

The association between age and health is stronger in the coal miners than in the foundry workers, but there is a distinct similarity between the distributions of men in Category A in the two tables. The proportion of men in good health declines to the early 60s and thereafter rises in the 65–69 age group, the upward trend continuing in the coal miners over age 70. It is likely that the change of direction around age 65 is due to some of the less fit men having retired on reaching national pension age, leaving their contemporaries in good health to continue at work. Some support for this view was obtained at interview, a number of men in Categories B and C intimating their intention to keep at work if possible until age 65 when pensions would begin.

Age, Health, and Work.—The last association to be examined is that between the state of health and the heaviness of work. In Tables 12 and 13 are set out the comparisons by age between the work distributions within each health category.

The smaller proportion of men on heavy work in Categories B and C is expected in view of their disability. The finding of note is that among the men in good health there is a steady decline with age in the proportion on heavy work though in the foundry data this could easily be due to chance. It is of course wrong to equate Category A with fitness for heavy work, but it does appear that the decline with age in the proportion of men on heavy work cannot be attributed to state of health as such unless the proportional distributions have been upset by losses between one age-group and the next, and of this, there is in this study, no actual measure.

Discussion

Reference has been made to the methodological difficulties which confined this study to older people at work. The resulting restriction on interpretation of the data has been discussed

TABLE 12

HEALTH CATEGORY AND "WORK HEAVINESS" IN THE TWO FOUNDRIES

Age Group	Category A			Category B			Category C		
	H	M	L	H	M	L	H	M	L
50–59	43 (37%)	58 (50%)	15 (13%)	4 (8%)	22 (45%)	23 (47%)	—	6	2
60–69	13 (21%)	35 (57%)	13 (21%)	3 (8%)	20 (54%)	14 (38%)	1	2	4
70+	—	6 (86%)	1 (14%)	—	—	3 (100%)	—	—	1
Total	56 (30%)	99 (54%)	29 (16%)	7 (8%)	42 (47%)	40 (45%)	1 (6%)	8 (50%)	7 (44%)
		$\chi^2 = 7{\cdot}86$ n = 4 P = 0·10							

H = heavy work. M = medium work. L = light work.

TABLE 13

HEALTH CATEGORY AND "WORK HEAVINESS" IN THE COAL-MINE

Age Group	Category A			Category B			Category C		
	H	M	L	H	M	L	H	M	L
50–59	56 (70%)	17 (21%)	7 (9%)	15 (42%)	14 (39%)	7 (19%)	2	2	1
60–69	15 (44%)	11 (32%)	8 (24%)	3 (10%)	13 (43%)	14 (47%)	—	—	2
70+	2 (15%)	7 (54%)	4 (31%)	—	—	—	—	—	—
Total	73 (57%)	35 (28%)	19 (15%)	18 (27%)	27 (41%)	21 (32%)	2 (29%)	2 (29%)	3 (42%)
		$\chi^2 = 17{\cdot}85$ n = 4 P = 0·01							

H = heavy work. M = medium work. L = light work.

in the appropriate places, but it must be stressed that without similar investigation of the same age groups in the unemployed and retired sections of the population who had worked in these industrial units, the picture is inevitably incomplete. Mindful of this limitation, answers to the four questions posed will be attempted. (1) Are older men doing less heavy work than their younger colleagues? There seems no doubt that, as between the 50s, 60s, and 70s, the answer is that as a group they are, in the foundries and coal-mine visited. To some extent this finding is dependent upon the opportunity for transfer to less heavy work which was probably greater than the nature of the work might suggest; thus the proportion of this particular colliery labour force aged 65 years and over was 4·1% compared with a figure of 3·3% for the whole mining population in that same year. During the investigation ample evidence was obtained of the enlightened and energetic managerial policy for the retention in useful work of older men.

(2) At what ages do men move to less heavy work? An attempt has been made to give some precision to the general impressions on this question; if the assumptions about those who retire are correct then the data show clearly that the incidence of change to lighter work is negligible in the 20s and 30s, begins to rise in the 40s, and thereafter rises steeply.

Reference has already been made to the sharp increase between the age groups 41–50 and 51–55 years in the upward trend of national unemployment (Table 1) and to the finding of Thomas and Osborne that the overall average age at retirement from full-time work was 62 years. There is some similarity between these trends and the way in which age at change to lighter work behaved in this study, and it is therefore tempting to regard retirement from full-time work, unemployment at later ages, and change to lighter work as being in part due to the same set of changes with age. In one sense (though not strictly that used in this paper)

both retirement and unemployment are work "modifications" and it may be that the premature occurrence of these events is in many cases because a suitable change, i.e., less heavy work, is simply not available. Statements made by several men in both foundries and coal-mine left no doubt that a number of men would have been forced into retirement or unemployment if lighter work had not been provided.

It is most important to realize that the problems connected with the employment of older men frequently arise some years earlier than 65 years. Unfortunately there are no statistical data to show the relative roles of heavy and light work in this respect but it is probable that the age of retirement is earlier, other factors being equal, in the heaviest jobs than in work as a whole.

(3) With what factors are these moves associated? Though illness, injury or disability resulting therefrom was stated to be the "cause" of nearly two-thirds of the moves to less heavy work, scrutiny of the recorded ailment and duration of absence, together with the frequent admission that strain had preceded the actual change to lighter work, left very little doubt that illness or injury often acted as a "trigger factor".

From the histories of those with good insight it appeared that the decision to seek less heavy work was often the result of some external suggestion by workmates, members of the family, or a doctor, acting on a mind made more receptive by an absence, even a short one, from work. It is common experience that during absence from work the subjective capacity for physical effort declines and has to be restored by a graduated return to work, but the nature of the objective psychological and physiological changes is obscure.

In his Linacre lecture on old age Rolleston (1922) observed that after an illness "old age often comes on apace". Is it possible that there are detectable changes in fitness and skill during and following absence from work through illness and injury even when clinical recovery is complete? Further speculation on the exact role of these events is useless but this would seem to be an important field for study.

Of the factors responsible even less is known. Reference has been made to the similarity between changes to lighter work preceded by ill health and some of those where no such history was obtained. The period of strain or increasing awareness of the demands of heavy work again emerged as the predisposing cause, the actual change appearing to follow some chance-determined event. The remaining men were convinced either that they had not moved to less heavy work at all—which was perhaps wishful thinking—or that such a move was the right thing to do in the 50s or 60s.

It cannot be too strongly stressed that conventional beliefs about age and work exerted a powerful influence in the groups interviewed. One of the most formidable tasks in the campaign to retain older workers in heavy industry will be to reduce the wastage of skill and of efficiency which results from this emotional rather than rational attitude to heavy work. There is certainly one direction in which much could be achieved—the alteration of payment-by-results to suit the older worker.

Increasing mechanization with its attendant acceleration of production speeds is extending the range of jobs to which piece-rates, output bonus schemes, and other incentives can be applied. These devices assume that high speeds of work are possible, an assumption known to be less and less correct as age increases. That time-rates are preferable to older men even when they imply a substantial drop in wages was the opinion of many of the men interviewed. Discussions with the foundry and mine managements revealed the manifold difficulties to be overcome if older men are to continue at their skilled tasks and at the same time be allowed some reduction of effort. But it would surely be more efficient and economical to keep skills in action at a lower level of output than to allow the present drift toward less skilled work to continue.

During the investigation two interesting examples of the efficient use of older skilled men were noted. In the coal-mine a few of the older strippers were transferred to a training coalface where the assistance of the young trainees reduced the effort and where the journey to and from the pit bottom was rather less hurried. In the large foundry several of the older men had been transferred to a new mechanized plant where, although the pace of work was strenuous and only younger men were recruited, their skilled knowledge enabled them to supervise without actually expending much effort. These illustrations serve to introduce an important principle for older men on heavy work: modify the effort but preserve the skill.

(4) Crude as the assessments were, the findings suggest that with a sound placement policy heavy industry can employ a considerable proportion of unfit men. One third of the whole group had some degree of disability and at least 5% were severely restricted in the work they could do.

It is, however, not easy to resettle older men in a coal-mine where the number of jobs requiring little effort is small. In the group interviewed eight men had certified pneumoconiosis but at least twice that

number were probable sufferers and the combination of dyspnoea due to ageing and to disease placed severe restrictions upon them. Yet, as has been pointed out, this colliery had a higher proportion of men over 65 in employment than the national average.

Some evidence was tabulated to suggest that retirements at age 65 were relatively commoner among the less fit men. Owing to the inaccessibility of those who had already retired it was unfortunately impossible to determine whether they had done so on health grounds, because suitable work was not available, or because they had no inclination to continue in employment beyond pensionable age. It was noticeable that the men still at work over 65 years of age had a " why should I retire " attitude to work. These points focus attention on the difficulties imposed by the fact that older people at work are highly selected.

Conclusion

Finally it is appropriate to reconsider the introductory recommendations on work which is suitable for older men. From the research on skill and fitness therein reviewed, it was shown that work which required a high speed of performance and a high expenditure of energy is in general unsuitable for the majority of older people. It might therefore be expected that when these conditions are combined older people would tend to move off such work.

In both foundries and coal-mine many older men were consciously aware of the strain imposed upon them by heavy work, and it appeared that their notion of heaviness comprised in varying degree the conditions mentioned above. Change to lighter work may therefore represent a process of adjustment to psycho-physiological strains, and if that suggestion is correct the main problem becomes one of how to permit that adjustment without sacrificing the productive skills involved, or, in other words, of " refining " the kind of change to lighter work described in this paper.

By way of peroration the words of Sir Frederic Bartlett (1951b)—than whom none is better qualified to speak—are fitting :

> " But it can be regarded as certain that, given adequate medical care and a proper regard for the conditions of training and work which are appropriate for the particular age-ranges concerned, the great bulk of the members of any modern community ought to be able, over the whole of a full life-span, to continue to contribute to the productive skills which are essential in such a community, and to do so without undue fatigue or strain but to their own happiness and satisfaction."

Summary

The core of the problem of age and work is how to retain older workers in industry. An important part of the solution is the definition of suitable work for those in the upper age ranges in terms of skill, fitness, and motivation ; some of the changes with age in these qualities are reviewed.

From the industrial standpoint the problem varies in nature. The scanty evidence on the relation between age and heavy work is discussed, and a study is reported in which 489 men age 50 years and over were interviewed in two foundries and a coal-mine.

Within the limits imposed by the fact that older people at work are highly selected, it is shown that the proportion of men on heavy work declined from the 50s onwards, and with this move off heavy work there was frequently a reduction in skill. The incidence of changes to less heavy work appeared to be low in the 20s and 30s, began to rise in the 40s, and thereafter sharply increased. The effect of selection upon this trend is discussed.

Illness or injury, both trivial and otherwise, was associated with two-thirds of the changes to lighter work. The suggestion is advanced that these and other events acted as " trigger factors ", the decision to change often being preceded by a period of increasing strain.

The role played by speed of work in determining decisions to change to lighter work is discussed ; the need is stressed for some reduction in work tempo as age increases and the view expressed that such reduction should not be at the expense of skill.

Some evidence is put forward that less fit men try to continue at work until age 65, their retirement having a selective effect upon the health distribution of those who carry on beyond that age. It is shown that even those in good health are to be found on less heavy work as age increases.

The problem of the relation of age and work appears some years earlier than pensionable age. The similarity between the trends with age in unemployment, retirement, and changes to lighter work is discussed.

To the National Coal Board (Scottish Division), the foundry managements, and the various trade unions I express grateful thanks for generous facilities and cordial cooperation. I am indebted to many colleagues but most of all to Mr. Alan T. Welford, M.A., Director of the Nuffield Unit for Research into Ageing at Cambridge, for his constant encouragement and wise counsel. Lastly, but very sincerely I thank the 489 men for this insight into *their* problem of age and work.

The statistical calculations were kindly checked for me by the staff of the Department of Statistics, University of Aberdeen.

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APPENDIX

TABLE A

RATES OF CHANGE TO LIGHTER WORK OF 50–54 and 55–59 AGE GROUPS

Age Period x	Small Foundry				Large Foundry				Coal-mine				Total			
	n	m	r	c	n	m	r	c	n	m	r	c	n	m	r	c
Men aged 50–54 years																
20–29	22	—	—	—	74	1	0·013	0·0013	66	—	—	—	162	1	0·006	0·0006
30–39	22	—	—	—	73	5	0·068	0·0068	66	4	0·06	0·006	161	9	0·055	0·0055
40–49	22	7	0·318	0·0318	68	19	0·279	0·0279	62	19	0·306	0·0306	152	45	0·296	0·0296
Men aged 55–59 years																
20–29	19	1	0·052	0·0052	58	1	0·017	0·0017	55	—	—	—	132	2	0·015	0·0015
30–39	18	—	—	—	57	2	0·035	0·0035	55	—	—	—	130	2	0·015	0·0015
40–49	18	1	0·055	0·0055	55	7	0·127	0·0127	55	7	0·127	0·0127	128	15	0·117	0·0117
50–54	17	4	0·235	0·047	48	9	0·187	0·0374	48	16	0·333	0·0666	113	29	0·256	0·0512

n = number of men entering each age period of x years with no history of modification.
m = number of men modifying in each age period x (x has only two values = 5 and 10 years).
r = crude modification rate $= \frac{m}{n}$
c = modification rate per year for each period $= \frac{r}{x}$

TABLE B

RATES OF CHANGE TO LIGHTER WORK OF 60–64 AND 65–69 AGE-GROUPS

Age Period x	Small Foundry				Large Foundry				Coal-mine				Total			
	n	m	r	c	n	m	r	c	n	m	r	c	n	m	r	c
Men aged 60–64 years																
20–29	10	—	—	—	48	1	0·02	0·002	39	1	0·025	0·0025	97	2	0·02	0·002
30–39	10	—	—	—	47	5	0·106	0·0106	38	—	—	—	95	5	0·052	0·0052
40–49	10	2	0·2	0·02	42	6	0·142	0·0142	38	3	0·078	0·0078	90	11	0·122	0·0122
50–54	8	—	—	—	36	5	0·138	0·0276	35	3	0·085	0·017	79	8	0·101	0·0202
55–59	8	1	0·125	0·025	31	8	0·258	0·0516	32	15	0·468	0·0936	71	24	0·338	0·0676
Men aged 65–69 years																
20–29	11	—	—	—	36	—	—	—	27	—	—	—	74	—	—	—
30–39	11	2	0·181	0·0181	36	1	0·027	0·0027	27	—	—	—	74	3	0·04	0·004
40–49	9	—	—	—	35	3	0·085	0·0085	27	1	0·037	0·0037	71	4	0·056	0·0056
50–54	9	1	0·111	0·0222	32	3	0·093	0·0186	26	2	0·076	0·0152	67	6	0·089	0·0178
55–59	8	2	0·25	0·05	29	8	0·275	0·055	24	3	0·125	0·025	61	13	0·213	0·0426
60–64	6	1	0·166	0·0332	21	8	0·38	0·076	21	10	0·476	0·0952	48	19	0·395	0·079

TABLE C

RATES OF CHANGE TO LIGHTER WORK OF MEN AGED 70–79 YEARS: FOUNDRY AND COAL-MINE DATA COMBINED

Age Period x	n	m	r	c
20–29	24	—	—	—
30–39	24	1	0·042	0·0042
40–49	23	1	0·044	0·0044
50–54	22	2	0·09	0·018
55–59	20	5	0·25	0·05
60–64	15	3	0·20	0·04
65–69	12	4	0·333	0·0666

MISCELLANEA

Charles Turner Thackrah in the Agitation for Factory Reform

GEORGE ROSEN

Habent sua fata libelli! And in many instances the thought is equally applicable to the men who wrote them. As a case in point consider the historical fate of Charles Turner Thackrah, surgeon of Leeds. His name occurs sporadically in histories of medicine. Usually, it is absent from the large general medical history, but may be found in monographs concerned with the development of public health or occupational medicine. Even in these, references to Thackrah are brief. Yet in the opinion of John Simon (1897) "one very important new line of thought in Preventive Medicine was opened for England in 1831, by Mr. C. Turner Thackrah, a surgeon of Leeds, who in that year published a work . . . on *The Effects of Arts, Trades and Professions, and of civic states and habits of living, on Health and Longevity* . . . By his eminently trustworthy book, he, more than fifty years ago, made it a matter of common knowledge, and of State responsibility, that, with certain of our chief industries, special influences, often of an evidently removable kind, are apt to be associated, which, if permitted to remain, give painful disease and premature disablement or death to the employed persons".[1] Clearly, Thackrah deserves to be better known.

Charles Turner Thackrah was born in Leeds on May 22, 1795.[2] Although destined by his mother for the Church, he was not interested in becoming a clergyman, and eventually decided to enter the medical profession. In 1811, he was apprenticed to Mr. O. Brooke, a surgeon of Leeds, with whom he studied for three years.

Even at this early period Thackrah already exhibited the devotion to duty and desire for knowledge which were to characterize his entire career. For example, in 1812, while carrying out the laborious duties of an apprentice, he found time to read thoroughly 25 books on medicine, history, and general knowledge, and to study 38 partially. During the next few years his reading increased extensively, shifting almost exclusively to professional subjects. In line with this passionate desire for knowledge is Thackrah's resolution of 1815 "to consume in sleep not more than eight hours in twenty-four, unless in case of sickness or disturbed rest, and to make himself acquainted each day with the nature and treatment of some disease". Undoubtedly related to this resolve is the practice initiated by Thackrah about this time of keeping records of medical cases, a practice followed constantly in his later career.

Following the termination of his apprenticeship, Thackrah, in 1814, enrolled as a student at the Leeds Infirmary. His medical education was completed at London, where he spent the winter of 1815–16 in attendance at Guy's Hospital. In October, 1815, he became a member of the Physical Society at Guy's. Thackrah was exceedingly diligent in his attendance at lectures and anatomical exercise, and it is said that Sir Astley Cooper took special note of him. In his diary he recorded that he usually applied himself to his studies from seven in the morning to half-past eleven at night. It is not entirely surprising that Thackrah contracted an internal ailment, which produced painful and profuse diarrhoea, from which he suffered intermittently for the rest of his life.

In the spring of 1816 he passed the qualifying examinations at Apothecaries' Hall and at the College of Surgeons. At the same time, Thackrah won a prize offered by the Physical Society of Guy's with an essay on diabetes. He then returned to Leeds where early in 1817 he set himself up in practice. Election to the position of town surgeon improved Thackrah's professional position, and his practice began to develop. It seems plausible to suggest that Thackrah's interest in the social aspects of medicine, especially those related to occupation, was stimulated by the patients and the medical problems encountered in his capacity of town surgeon. Further stimulation in this direction very likely resulted from a request to Thackrah by the managing committee of the Leeds workhouse that he investigate lodging-houses for the poor. The report which he presented showed in striking fashion the miserable and unhygienic conditions existing in these establishments, and led to measures aimed at improving the situation.

At the same time, while carrying on a growing practice, and dealing with health matters of concern to the community, Thackrah did not neglect the scientific basis of medicine. His interest in anatomy, physiology, and pathology continued unabated, and in 1817 he began to investigate the nature and properties of blood. Based on these studies, he prepared the monograph, *An Inquiry into the Nature and Properties of the Blood, in Health and Disease*, which appeared in 1819. Before its publication this work had won for its author a prize given annually by Sir Astley Cooper to his students for the best dissertation on a subject proposed by himself.

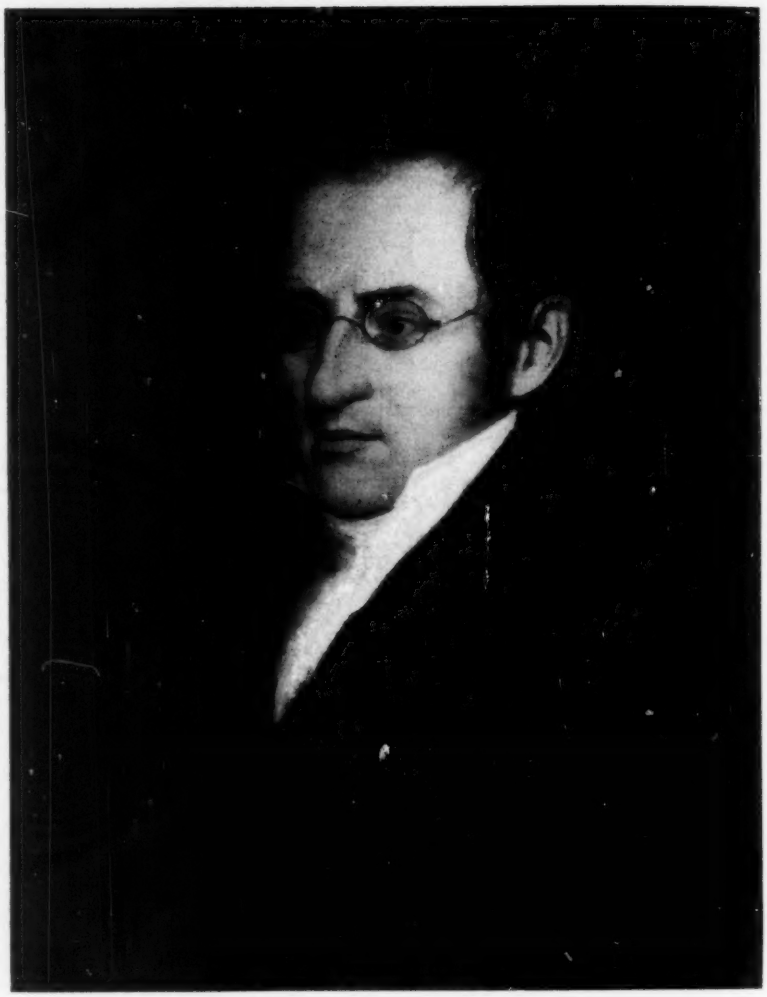
In addition to his other interests, Thackrah had a lively concern for the problems of medical education. As early as 1820 he joined several other young physicians in arranging to give to their pupils a series of lectures on various branches of medicine. It is interesting to note that his own students received exercises in the classics and in English composition, in addition to exercises in drawing up necropsy reports and taking notes on medical cases. This profound and active interest in medical

1. Simon, John (1897). English Sanitary Institutions, 2nd ed., pp. 125–127. Smith, Elder and Co., London.

2. The chief source for Thackrah's biography is H. Y. Whytehead (1834) Biographical Memoir, in C. Turner Thackrah *An Inquiry into the Nature and Properties of the Blood in Health and Disease*, pp. 9–20, new and enlarged edition, Longman, Rees, Orme, London.
Confirmatory information on several points, particularly on Thackrah's relation to the Leeds medical school, is presented by J. Ingham Ikin (1851), "On the progress of public hygiene and sanitary legislation in England, and the advantages to be derived from their further extension", *Provincial Medical and Surgical Journal*, p. 538.

education led Thackrah early in 1826 to consider the formation of an anatomical school ; and in May 1827, he completed his first lecture course on anatomy. According to Dr. Ikin, his fellow-townsman, this was the "first public course of anatomical lectures" in Leeds.[3] It was followed by a second series of lectures in the spring of 1828 ; but despite these efforts his applications to the College of Surgeons and to Apothecaries' Hall to have his certificates to students admitted were rejected. In 1831, however, Thackrah's ideas on medical education were realized when he, together with several other physicians established the Leeds Medical School.[4] During the sessions of 1831–32 and 1832–33 he lectured at the school on anatomy, physiology, pathology, and surgery.

The year 1831, however, was important in Thackrah's career for still another development. In this year he published the first edition of his pioneer work, *The Effects of Arts, Trades and Professions . . . on Health and Longevity*. The reception accorded this work by the medical profession and the general public was exceptionally favourable. The first edition was soon exhausted, and a second, enlarged edition appeared in 1832. Sometime around 1824, Thackrah had begun to study how manufacturing processes affected the health of workers. As physician to the Leeds Infirmary, he had numerous opportunities to observe disordered states of health in various kinds of workers.



CHARLES TURNER THACKRAH

Reproduced by kind permission of the Board of Management of the General Infirmary at Leeds.

> "Myself and my pupils", he pointed out, "have personally and carefully inspected the state of the agencies believed to be injurious, conversed on the subject with masters, over-lookers, and the more intelligent workmen, and obtained many tables illustrating the character of the disorders prevalent in the several kinds of employ. From these sources collectively, and my own observations in practice, I have drawn up statements, which, though avowedly imperfect, must, I conceive, approach to the truth."[5]

Thackrah's object was to attract public attention to the problem of preventable ill-health as related to occupation and similar factors so that action could be taken to deal with them. In this aim he succeeded better than he had perhaps anticipated. The great political uprising which culminated in the Reform Act of 1832 was nearing its height. At the same time, the industrial workers were organizing not only for political agitation but as well for improvement of conditions in the factories. Their chief demand was the restriction of hours of labour specifically for children, and the publication of Thackrah's book came at the right moment in support of this social reform.

Leading the campaign in the West Riding was Richard Oastler, who in 1830 had set out to abolish "Yorkshire slavery", that is, child labour. Oastler had come to know Thackrah soon after he had begun to agitate for factory reform, and had been assured of his wholehearted support in the endeavour to restrict child labour.[6]

3. Ikin, J. Ingham (1851). *Ibid.*, p. 539.

4. Ikin makes the following comment: "I must also, in bare justice, couple his name with the earliest founders of provincial medical schools . . . his exertions ultimately gave origin to the more effective organization of the Leeds Medical School . . ." See *op. cit.* p. 539.

5. Thackrah, C. Turner (1832). *The Effects of Arts, Trades, and Professions, and of Civic States and Habits of Living, on Health and Longevity*, p. 6. 2nd ed., greatly enlarged. Orme, Brown, Green, and Longman, London.

6. Driver, Cecil (1946). *Tory Radical. The Life of Richard Oastler*, p. 73. Oxford University Press, New York.

In March, 1831, Oastler wrote a letter to the *Leeds Mercury* commenting on the factory controversy, in which he made use of Thackrah's recently published book. According to Thackrah :

> " No man of humanity can reflect without distress on the state of thousands of children, many from six to seven years of age, roused from their beds at an early hour, hurried to the mills and kept there with an interval of only forty minutes till a late hour at night ; kept moreover in an atmosphere impure not only as the air of a town, not only as defective in ventilation, but as loaded also with noxious dust."

Thenceforth, Thackrah and his book were enlisted in the continuing campaign to improve working conditions in factories. As the movement for factory reform developed, it became evident that the work of the children was inextricably bound up with that of the adults. Consequently, the establishment of a reasonable working day for children involved also the regulation of adult labour. In April, 1831, Oastler issued a manifesto *To the Working Classes of the West Riding* in which he formulated the clear-cut objective of the 10-hour day, and set in motion a movement which was to have incalculable consequences for British social politics.

Toward the end of 1831, Michael Sadler, recently elected to Parliament, introduced a Ten Hours Bill. Proponents of the measure realized the immediate need for mobilizing public opinion on its behalf, and planned to hold a series of meetings to rouse the workers and the general public. The third of these meetings was held at Leeds in January, 1832. On the platform was a distinguished group of notables, including opponents as well as advocates of Sadler's bill. Among them was Thackrah,[7] who is reported to have presented the case for regulation of working hours with vigour and realism. He buttressed his presentation by citing the cases of some of his child patients. Was it any wonder, with such conditions, he asked, that the coming generation was unable to resist the onslaught of disease ?

On March 16, 1832, Sadler in a brilliant three-hour speech moved the second reading of his bill. His presentation was solidly grounded in logic and fact. As part of the evidence to prove the need for legislation, he described the shocking working conditions in many factories and their effect on the worker's health. In support of his contention, Sadler cited the evidence of medical men with experience in this field, among them Thackrah. Sadler had received a copy of Thackrah's work on the effects of occupation on health and disease, and he made good use of it.[8]

Unfortunately, Thackrah did not live to see the ultimate triumph of the cause he had espoused. Despite poor health, he continued to labour indefatigably on medical and public health problems. The prevalence of cholera in 1831–32 led him to visit Newcastle and Gateshead, and resulted in a pamphlet on the disease which was favourably received by the profession. Thackrah also continued the preparation of a new edition of his monograph on the blood. In 1833, however, the condition of his health began to deteriorate rapidly. The gastro-intestinal condition with which Thackrah was afflicted was complicated by pulmonary disease, and he died on May 23, 1833.

Despite his premature death, Charles Turner Thackrah left an indelible imprint on the social and medical development of Great Britain. Writing in 1851 on the progress of public health in England, Ikin pointed out that

> " The political promoters and agitators for the promotion of factory legislation, though often led astray by their zeal and enthusiasm, deserve the gratitude of their country ; and, in the progress of this, to us . . . exciting question, the aid, co-operation, and testimony of the members of the medical profession tended more than any other influence to compel the interference of the Legislature." [9]

In this company Thackrah occupies not only an honoured place ; he stands out far ahead of his contemporaries. Not only did he recognize the social responsibility of the physician to his community and act on it, but he also laid the foundation for the study of occupational health in Great Britain. His work continued to be used after his death by all those interested in dealing with the health problems raised by the new industrial civilization.[10] Thackrah's work was well conceived, based on wide research, and above all imbued with social consciousness. He crowded much into his short life, but it was pregnant with profound meaning for the future.

7. Driver, Cecil (1946). *Ibid.*, pp. 135–136.

8. I have a copy of the 1832 edition bearing the inscription : " M. T. Sadler Esq., M.P. with respectful compliments of the author ".

9. Ikin, J. Ingham (1851). *Ibid.*, p. 539.

10. For example, P. Gaskell (1836) *Artisans and Machinery*, John W. Parker, London ; John Wade (1835) *History of the Middle and Working Classes*, 3rd ed., Effingham Wilson, London ; Benjamin W. McCready (1837) *On the Influence of Trades, Professions, and Occupations in the United States, in the Production of Disease*, New York. [Orig. publ. in *Trans. med. Soc. st. New York*, 3, Appendix p. 25.]

A Mobile Consulting Room*

G. O. HUGHES

From the North Western Gas Board

In an industry whose employees are scattered in small groups over a wide area medical examinations present a problem which does not arise in an industry with a large population in a small area. There are several possible ways of meeting this problem.

Examination centres can be set up at a small number of convenient points to which the employees can travel. This usually means the loss of half a day or a day's work in addition to travelling expenses.

Examination centres can be set up at each work place, either using accommodation intended for another purpose or using rooms specially built for the purpose at each place. The choice lies between unsatisfactory or costly consulting rooms. Examinations can be carried out by general practitioners at fees varying from 10s. to 3 guineas. The service given and the interest taken by general practitioners varies considerably, and while some make excellent industrial medical officers others do not.

A mobile examination centre overcomes many of these disadvantages. It can be used by a doctor who is fully conversant with the industry ensuring that medical examinations are done with the demands of the job and the health hazards of the industry in mind.

The mobile consulting room here described is used by the North Western Gas Board, which has 20,000 employees working in an area covering 4,000 square miles. The area extends from the Lake District to the southern border of Cheshire, and from Buxton across to the west coast.

In Manchester and Liverpool there are large enough concentrations of employees to justify the establishment of ordinary consulting rooms. A third consulting room and office is also sited near St. Helens. The more isolated industrial areas of Lancashire and Cheshire beyond a 10-mile radius of these three medical centres are served by the mobile unit.

The unit is used primarily for medical examinations, though it can also be used as a treatment centre. New entrants into the industry, employees returning to work after accident or serious illness, and employees needing special medical assessment, are examined in the unit.

This unit has proved well worth while during the two months it has been in use. Its special features are set out below :—

Vehicle.—This vehicle is an Austin 2-ton long wheelbase chassis, with special springing and large capacity, and coach-type battery. The interior is 16 ft. × 7 ft. 6 in. The consulting room is 12 ft. × 7 ft. 6 in. and the two dressing rooms at the rear are each 3 ft. × 4 ft. The interior height, floor to ceiling, is 6 ft. 6 in.

Lighting.—The main lighting is derived from three fluorescent tubes operating from a battery or mains.

Heating.—Tubular radiators pass through the consulting room and also heat the dressing rooms. Hot water circulates from the engine cooling system and after about 20 minutes running remains hot for two to three hours. Additional heat comes from a gas convector radiator fire.

Water Supply and Drainage.—A 10-gallon water storage tank is carried beneath the vehicle. An "ascot" instantaneous gas water heater provides warm, hot, or boiling water. A 15-gallon waste tank is also sited beneath the vehicle. These tanks are accessible from outside for filling and emptying.

Sink Unit.—A stainless steel sink unit 54 in. × 21 in. has the usual drainer and two sinks. One is 14 in. × 18 in. × 7 in. for ordinary use : the other smaller one (14 in. × 5 in. × 5 in.) is for the disposal of urine specimens. The drainer makes a useful instrument tray. Beneath the sink a "calor" gas cylinder is stored. Here also is the electric centrifugal water pump.

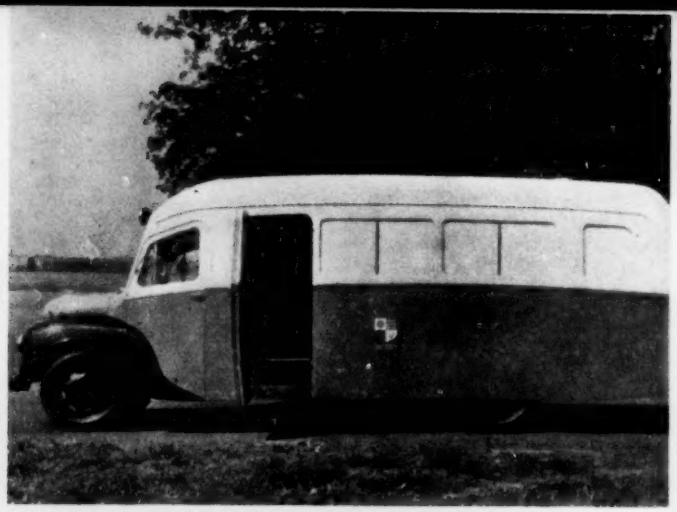
General Construction.—The body is double panelled and heat insulated, the outer panelling being aluminium alloy. The two rear doors, in appearance like ambulance doors, open each into a dressing room. Sliding doors separate the dressing rooms from the consulting room. These doors are so arranged that only one dressing room can communicate with the consulting room at one time. There is ample cupboard and storage space. The vehicle looks like a large motor ambulance. It is not too unwieldly to manoeuvre through some of the narrow streets of Lancashire into smaller gas works. At the same time it is of adequate size for the job.

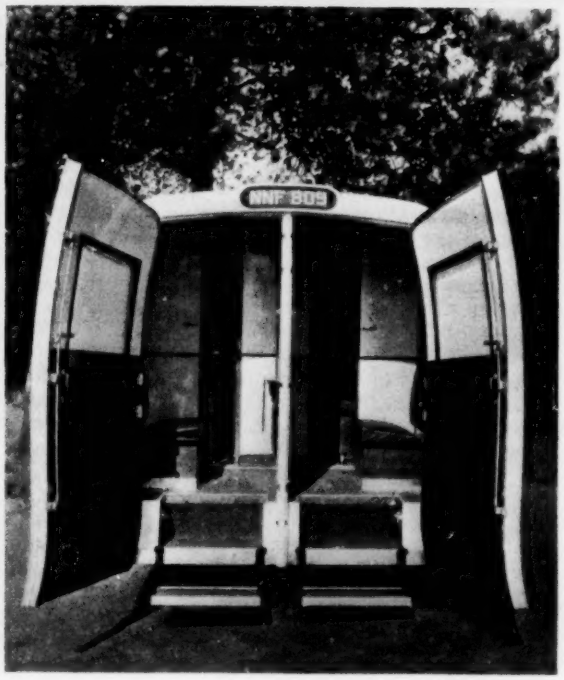
Design.—The design was drawn up by the Chief Medical Officer and the Transport Officer of the North Western Gas Board. The bodywork was built by Messrs. Herbert Lomas Ltd., ambulance specialists, of Manchester.

Costs.—The cost of the vehicle including accessories was approximately £2,500. The running costs are estimated as £750 per annum.

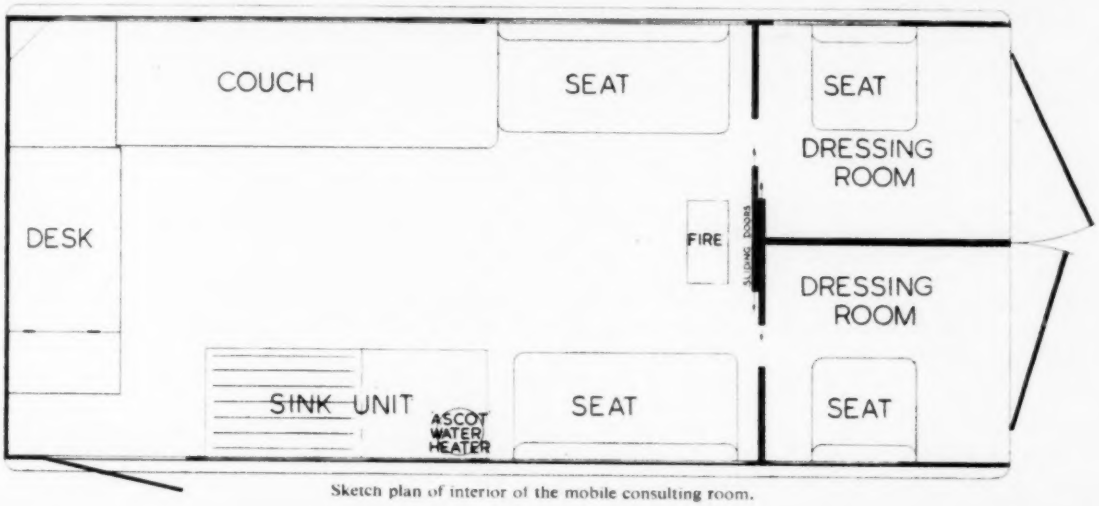
Working Capacity.—On a basis of 20 patients per day and allowing for travelling time, the unit can deal easily with 5,000 patients per annum, using it five days per week. In actual use it is anticipated that about 4,000 patients a year will be seen in the unit.

*Received for publication July 31, 1953.





Mobile consulting room showing the two dressing rooms at the rear and the medical officer's room. [*Photographs reproduced by courtesy of Messrs. Lookers Ltd., Manchester, 3.*]



Sketch plan of interior of the mobile consulting room.

BOOK REVIEW

International Labour Organisation. Third International Conference of Experts on Pneumoconiosis. Sydney. February–March, 1950. Record of Proceedings. Vol. I, Part 1 : Proceedings ; Part 11 : Papers presented to the Conference (pp. 323, mimeographed). Vol. II : Papers presented to the Conference and Index (pp. 337, mimeographed). Geneva : International Labour Office. 1953.

These two volumes contain a vast amount of information on pneumoconiosis, which has come, during this century, to be recognized as the outstanding occupational disease. It came into notoriety with the recognition of silicosis with tuberculosis superimposed. At first the tendency was to regard silica dust as the one toxic dust, next asbestos demonstrated its power for evil, and others followed, among which anthracite and coal are now the chief.

The contents of these two volumes are evidence of the research already done and of that in progress, and also of the world-wide recognition of the importance of the pneumoconioses. The conference which took place in Sydney was attended by experts from Norway, Sweden, France, Great Britain, the Netherlands, Belgium, British Columbia, Western Australia, South Africa, the United States of America, Canada, and other countries.

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E. L. Collis

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BOOK REVIEW

International Labour Organisation. Third International Conference of Experts on Pneumoconiosis. Sydney. February–March, 1950. Record of Proceedings. Vol. I, Part 1 : Proceedings ; Part 11 : Papers presented to the Conference (pp. 323, mimeographed). Vol. II : Papers presented to the Conference and Index (pp. 337, mimeographed). Geneva : International Labour Office. 1953.

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Some New Toxic Woods : Some New Manifestations of Toxicity. DANTIN-GALLEGO, J., and ARMAYOR, A. F. (1952). *Industr. Med. & Surg.*, **21**, 41.

This is a short account of toxic reactions among workers in a saw-mill in Spain to a particular shipment of woods of the mahogany type coming from West Africa. A large number of cases occurred [of which only 5 are described], mostly of naso-pharyngeal and respiratory catarrh with haemoptysis, or of dermatitis. The possible aetiology of these cases is described [rather superficially]. The yare thought to have been allergic in origin and might conceivably have arisen from fungi growing in the wood. *C. M. Fletcher.*

INDUSTRIAL LUNG DISEASES

Pneumoconiosis in Boiler Scalers. DUNNER, L., HICKS, M. S., and BAGNALL, D. J. T. (1952). *Brit. J. Tuberc.*, **46**, 43.

Pneumoconiosis is not uncommon in men engaged in scaling the boilers of ships, and the authors describe 25 cases seen at Hull. The working conditions in this job are far from good : the space is confined and the air is full of dust. This dust is of two kinds : (*a*) boiler scale dust ; and (*b*) flue dust (soot). Analysis of the former indicated a free silica content of 1·1% and of the latter up to 10·5% ; iron dust was also present.

Individual susceptibility to the development of pneumoconiosis varied ; symptoms also varied and were not always proportional to the radiological appearances. Melanoptysis (black sputum) was sometimes observed ; this was ascribed to cavitation of black foci in the lung. The radiological appearances varied from " increased linear striation " to nodulation (stated to be not always bilateral or symmetrical) ; in some cases there was nodulation with typical coalescent masses. A pattern of irregular running strands of fibrosis is also described. The chief complications were tuberculosis (4 cases) and carcinoma (4 cases, 3 of primary bronchial carcinoma).

The relation between the radiological findings and the morbid anatomy is discussed, but as the data were incomplete no clear correlation was possible : in one case typical silicotic nodules were seen at necropsy. It is pointed out that in Great Britain boiler scalers are not at present eligible for compensation. *L. W. Hale.*

Pneumoconiotic Changes in the Lungs of Graphite Workers. MÜLLER, H. (1952). *Fortschr. Röntgenstr.*, **76**, 452.

This paper is concerned with pneumoconiosis arising in graphite workers in two factories in Germany in which crude graphite was prepared and ground, and mixed with fireclay, ferro-silicon, and silicon carbide for the manufacture of crucibles ; 3 cases from one factory are described and illustrated. At the other factory, 53 workers in the dustiest parts of the factory were examined radiologically, and in 15 cases signs of pneumoconiosis were found, in 10 of which the condition was incipient (Stages 0 or 1). With 3 exceptions among the graphite millers all the men had been exposed to graphite dust for more than 15 years.

Symptoms were slight except in the older men with advanced disease. Breathlessness predominated, with cough, occasional black sputum, and chest pains. (No dust counts were done, nor was any chemical analysis of the airborne dust carried out.) The crude graphites used came from various sources and their total silica content ranged from 3 to 25%. After discussing other published accounts of graphite pneumoconiosis and pneumoconiosis arising in soot workers, the author remains uncertain whether the changes are due to the carbon in the graphite, or to the mineral contaminants. He urges that compensation should be granted to men who develop graphite pneumoconiosis.

C. M. Fletcher.

A Follow-up in 1950 of 463 Cases of Silicosis Admitted to the Industrial Medicine Clinic of the University of Milan between 1943 and 1947. BALDI, G. (1952). *Med. d. Lavoro*, **43**, 147.

In a follow-up in 1950 of 539 cases of silicosis examined at the University Industrial Medicine Clinic in Milan between 1943 and 1947, 463 patients were traced, of whom 212 had died. The cause of death was known in 98 of the 212, 69 having died of silico-tuberculosis and 16 of heart failure secondary to silicosis. The 463 traced patients were classified on the basis of the initial radiograph into cases of reticular fibrosis (11%), nodular silicosis (44%), massive silicosis (33%), and silico-tuberculosis (12%). The results were analysed to show the effect upon prognosis of the initial radiological stage, occupation before the first attendance, and occupation during the period of follow-up. There was a steady deterioration in prognosis in proceeding from the patients with reticular fibrosis to those with silico-tuberculosis, of whom 89% had died. The worst prognosis in terms of fatality and radiological progression was found in miners and workers engaged in grinding quartz. The lowest mortality and progress was found in foundry labourers. Evolution was also more rapid in those workers who contracted the disease after a short time of exposure to risk in especially dangerous occupations than in those in whom it appeared after more than 25 years' work. (There is no comment on the inevitable confusion between age and industrial exposure here.) Among the 251 survivors the effect of occupation during the period of follow-up was studied, and the results are given in the following table :—

INITIAL FORM OF SILICOSIS	NUMBER OF CASES		STATIONARY %		PROGRESSION %		SEVERE PROGRESSION %	
	A	B	A	B	A	B	A	B
Reticular	22	22	50	32	50	45	—	23
Nodular	44	105	34	23	59	53	7	24
Massive	12	40	17	15	58	55	25	30
Silico-tuberculosis	—	6	—	(17)	—	(83)	—	—

A — Continuing in dusty employment.
B — Not continuing in dusty employment.

The author concludes that " the evolution of nodular and massive silicosis appeared to be unconnected with cessation or prolongation of work in a dusty environment ". (In fact the figures given in the table suggest that progression was more severe in those who left their previous work. Presumably these patients were more severely ill, so that the two groups are not comparable.) He also concludes that in giving advice concerning the desirability of any patient's continuing to work in a dusty atmosphere the rapidity of the onset of silicosis must be considered. Those in whom the disease sets in in a relatively rapid form should be withdrawn, particularly in the early stages. The danger of a given occupation must be judged not only in terms of the prevalence of silicosis, but also of the usual rapidity of evolution of the disease. Prognosis, as well as present disability, should be considered in assessing compensation in cases of silicosis. *C. M. Fletcher.*

" Egg-shell " Opacities in Silicosis. FOUBERT, P., BALGAIRIES, E., DECLERCQ, G., and MASSINON, J. A., (1952). *Arch. Mal. prof.*, **13**, 263.

The authors describe and discuss 19 cases of " egg-shell " calcification (17 in coalworkers, 1 in a pottery worker, and 1 in a foundry worker). The radiographic appearance is that of somewhat circular, dense shadows at the hilum with a more translucent centre, usually bilateral, and occurring in clusters. In the authors' experience the condition is uncommon in coal miners, occurring in only 0·2% of 4,000 cases. This is a much lower frequency than that described in other occupations by various authors.

The pathogenesis is attributed by the authors to the combination of tuberculous infection with silicosis, but in addition a " calcification diathesis " is invoked. Other workers have described egg-shell calcification in men without silicosis, but the present authors believe that this is exceedingly rare, and they consider egg-shell opacities as pathognomonic of silicosis.

C. M. Fletcher.

Diffuse Pulmonary Granulomatosis in Young Women following Exposure to Beryllium Compounds in the Manufacture of Radio Tubes. Further Observation and Report of Nine Additional Cases. SLAVIN, P. (1952). *Amer. Rev. Tuberc.*, **65**, 142.

A full account is given of 9 further cases of lung disease due to exposure to beryllium in the manufacture of radio valves and electric lamps. In 4 cases which came to necropsy the lungs were analysed for beryllium. There were considerable differences between the results of analyses performed independently by 2 laboratories, and no correlation was found between the amounts of beryllium recovered and the extent of the pulmonary disease. One case was treated with ACTH (corticotrophin) without benefit. The severity of the disease and the disappointing response to treatment are emphasized.

C. M. Fletcher.

INDUSTRIAL PSYCHOLOGY

Man and the Machine. The Problem of Boredom. VITELES, M. S. (1952). *Travail, hum.*, **15**, 85. Bibliography.

The paper refers to a number of investigations, carried out over the last 30 years by industrial psychologists, into the response of the human being to continued, repetitive work. The monotony of such work is reflected in irregularity in output and in more or less open dissatisfaction with working conditions. Workers differ in their susceptibiltiy to this type of fatigue, but it should be possible to devise suitable selection tests. More important is the need to fit the task to the worker.

Boredom can, however, be alleviated by substituting a certain amount of variety for absolute uniformity, without any sacrifice of efficiency. Experiments have shown that properly spaced rest pauses, an opportunity for workers to engage in conversation, and " music while you work " are likely to alleviate the effects of repetitive work. It is emphasized, however, that no single remedy exists for the boredom and other effects of monotonous work.—(From the English summary.)

Life Stress and Industrial Absenteeism—the Concentration of Illness and Absenteeism in One Segment of a Working Population. HINKLE, D. E., and PLUMMER, N. (1952). *Industr. Med. & Surg.*, **21**, 363.

A study was carried out among a population of 1,297 women, mostly telephone operators, employed by the New York Telephone Company. They constituted a homogeneous group with regard to working conditions, age of starting, income, and residence, and all had passed a medical examination on entrance. The authors calculated from the attendance record of each employee the frequency and duration of absence during 1950 and during the first year of service and the annual averages over the whole period of service. It was found that one-third of the employees accounted for 80% of the time lost by absence during 1950 and a similar proportion of the total periods of absence. Moreover, the same group of employees was responsible for a disproportionate amount of absence year by year. High supervisors' ratings in respect of attitude and ability to mix showed a positive correlation with low frequency of absence during the first year's service (before any knowledge of the employee's attendance record could influence the supervisors' ratings), but high quality of work was only less definitely correlated with low absenteeism.

Medical and life histories were obtained from their records and by interview from 20 women with low and 20 with high absence rates, selected from the 336 with at least 20 years' service. The incidence of major and minor disorders of all organ systems, operations, accidents, and " psychoneurotic " illnesses was very much greater in the latter group, whose life histories showed greater exposure to " life stress ". The healthy women on the whole were content and secure, had no unalterable goal in life, and readily adapted themselves to changes in type or place of work, whereas the others had suffered

from repeated frustration, deprivations, emotional conflicts, and burdensome home responsibilities, and were ambitious, suspicious, and intractable at work. It is suggested that early recognition of such individuals is possible, as is ameliorative adjustment of the work situation. (The numbers in these groups are very small; the method of selection is largely responsible for the observed picture, and there is no evidence as to the validity of the judgments on "life stress.")

H. F. King.

The Human Factor in Industrial Accidents. PANCHERI, G. (1952). *Rass. Med. industr.*, **21**, 186.

The author summarizes the findings of various investigations into the causation of industrial accidents and adds some examples from his own experience. Quoting Greenwood's original demonstration in 1919 that workers exposed to equal risks may have different accident rates, he accepts it as proved that excessive proneness to accident is not due in any way to previous accidents. (This is not as yet accepted by all investigators.) In the search for a human causative factor as distinct from a technical one, an important preliminary is that factory accidents should be analysed not only in relation to their material causes, but also to the sort of action by the worker which gave rise to the accident. In this connexion the Bureau of Labor Statistics in the U.S.A. is experimenting with a form of report which should provide the basis for a valuable classification of causes of this type. The degree of exposure to risk and the gravity of the accident must also be considered, and simple indices of frequency and seriousness of accident are suggested. The importance of the human factor, which has been variously estimated at between 40% and 90%, clearly depends partly on the type of work.

Among the physical and psychological causes of accidents listed by the author are: lack of strength, sensory defects, age and sex, fatigue, nervous diseases, and emotional instability. On the other hand, physical type is not correlated with proneness to accidents, since the accident rate among young workers is higher than among the middle-aged. Women appear to have a lower accident rate than men, although on physical and psychological grounds they would be expected to be more prone to accidents; this is probably to be explained by a lower exposure to risk. There seems to be no relation between intelligence-test scores and proneness to accidents, except when intelligence is very low. In general, verbal tests seem to be useless for the detection of accident-proneness, but some aesthetokinetic tests, such as those of Farmer and Chambers, have proved valuable. The main responsibility for avoidance of accidents still rests with the technician, though the factory doctor should concern himself with the collection of relevant statistics and with the selection of workers.

(The author's approach is mainly intuitive; he does not deal at all with the difficulties ofinterpreting accident statistics, nor with some of the more recent laboratory work [see Whitfield, "Notes on the Causes of Accidents" (*Brit. med. Bull.*, 1950, **7**, 73)].) *Violet Cane.*